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Geotechnical and Structures Laboratory

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Development Center

Development of Laboratory Testing Criteria for Evaluating Cementitious, Rapid-Setting Pavement Repair Materials

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Abstract: Numerous commercial-off-the-shelf products are available for small surface repairs in portland cement concrete (PCC) pavements that provide short set times, high early strengths, and durability to withstand heavy loads. Investigations of pavement repair materials conducted at the U.S. Army Engineer Research and Development Center (ERDC) in Vicksburg, MS, and other test organizations examined cementitious rapid-setting repair materials for repair of PCC pavements through laboratory and field characterization. Standard laboratory tests were performed to characterize the material properties over time and to provide a mechanism for assessing the material suitability for field repairs. Numerous repairs were constructed and evaluated under controlled traffic conditions to determine the ability of the repairs to support aircraft traffic after a minimum curing period. A laboratory protocol was developed for selection of cementitious, rapid-setting repair materials based on the laboratory and full-scale test results. This protocol originally developed in 2006, aided airfield managers and repair teams by reducing the potential for selection of materials that were likely to perform poorly. Changes to the protocol were made based on a review of material properties and field performance of materials tested at ERDC and other test agencies to improve the process of selecting materials based on repair type and size.

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Preface

This report was written for use by the U.S. Air Force's (USAF) pavement evaluation teams, contingency readiness groups, base civil engineers, major command pavement engineers, Rapid Engineer Deployable, Heavy Operational Repair Squadron, Engineer (RED HORSE) squadrons, and Prime BEEF (Base Engineer Emergency Force) units. Additional users of this report include Army, Navy, and Marine Corps units charged with the repair and sustainment of damaged airfield pavements.

The project described in this report was funded by the Air Force Civil Engineer Support Agency (AFCESA). The technical manager for this project was Dr. Craig Rutland of the AFCESA, Panama City, Florida.

This publication was prepared by personnel of the U.S. Army Engineer Research and Development Center (ERDC), Geotechnical and Structures Laboratory (GSL), Vicksburg, MS. The findings and recommendations presented in this report are based upon laboratory evaluations conducted during the period February through July 2010. The principal investigator for this project was Lucy P. Priddy of the Airfields and Pavements Branch (APB), GSL.

This report was prepared by Priddy. The testing and analyses were conducted under the supervision of Dr. Gary L. Anderton, Chief, APB; Dr. Larry N. Lynch, Chief, Engineering Systems and Materials Division; Dr. William P. Grogan, Deputy Director, GSL; and Dr. David W. Pittman, Director, GSL.

COL Kevin J. Wilson was Commander and Executive Director of ERDC. Dr. Jeffery P. Holland was Director.

Unit Conversion Factors

Multiply	By	To Obtain
degrees Fahrenheit	(F-32)/1.8	degrees Celsius
feet	0.3048	meters
gallons (U.S. liquid)	3.785412 E-03	cubic meters
inches	0.0254	meters
ounces (mass)	0.02834952	kilograms
ounces (U.S. fluid)	2.957353 E-05	cubic meters
pints (U.S. liquid)	4.73176 E-04	cubic meters
pints (U.S. liquid)	0.473176	liters
pounds (force)	4.448222	newtons
pounds (force) per foot	14.59390	newtons per meter
pounds (force) per inch	175.1268	newtons per meter
pounds (force) per square foot	47.88026	pascals
pounds (mass)	0.45359237	kilograms
quarts (U.S. liquid)	9.463529 E-04	cubic meters
square feet	0.09290304	square meters
square inches	6.4516 E-04	square meters

1 Introduction

Problem statement

Rapid pavement repair technologies for airfield pavements have become critical to pavement repair and rehabilitation because of the demand to minimize the time the pavement is out of service, particularly during contingency operations. Depending on the size of the damaged area, these repairs require small or large volumes of repair material. Small volume repairs would generally be small patches (surface area of 5 ft^2 or less) either partial-depth or full-depth; large volume repairs would be considered any repair from full-depth large patches (surface area greater than 5 ft^2) to full-slab replacement.

Regardless of size of the needed repair, the pavement must be closed to traffic to safely conduct repair activities. Such closures result in airport delays, safety hazards, and reduced operational tempo for military operations. Often the available time for closure of a critical runway may be as short as 4 hr, and this window may be even further reduced due to specific operational requirements. Because of these short repair windows, the proper selection of materials for repairing these pavements is absolutely essential. Selecting the proper material reduces the likelihood of accidents, the potential for delays, the need for future maintenance efforts and accompanying service interruptions that could result from the selection of a poor-quality product.

Existing specifications for conducting repairs of portland cement concrete (PCC) on airfields are intended for longer repair windows (7 to 28 days). Unfortunately, the time available for conducting repairs may be limited to only a few hours either at night or during other periods of low traffic operations. Traditionally, conventional PCC is the material of choice and provides the best results for permanent repairs. However, over the past several years the performance of proprietary rapid-setting patching materials has improved, making their use acceptable for a wide range of repair types while providing rapid return to service.

Numerous commercial-off-the-shelf (COTS) rapid-setting repair products provide short set times, high early strengths, and good durability. Due to this combination of advantageous characteristics, these materials exhibit

great potential to meet the challenges of rapid pavement repair of PCC pavements.

The use of rapid-setting materials is not new. Much research has been focused on the development of methods of evaluating the wide spectrum of materials being marketed to state departments of transportation (DOTs) and military pavement engineers over that last 20 years. Field testing of these materials resulted in identification of problems with short working times at both ambient and high temperatures, with excessive shrinkage cracking, and with batching quantities needed for repairs (Macadam et al. 1984; Parker et al. 1985; Ramey et al. 1985; Popovics and Rajendran 1988). These problems have been alleviated by a newer generation of products with modern cementing components. Unfortunately, habitual repackaging and reformulation of these products by manufacturers have resulted in serious pavement repair failures with some of the products despite previous good repair results with ostensibly the same product (Priddy et al. 2007). Thus, unless the material has recently undergone testing to verify the properties, the design engineer cannot be confident that the material will meet performance expectations. To combat this problem of repackaging and reformulation, The American Association of State Highway and Transportation Officials (AASHTO) recommends that products be retested every 5 years through the National Transportation Product Evaluation Program (NTEP) (http://www.ntpep.org/).

The use of unproven products and techniques poses significant risk to aircraft and vehicles due to foreign object debris (FOD) damage (Priddy et al. 2007; Mann 2006). This occurs when the repairs crumble, and the loosened material is projected at the aircraft (or vehicle) or ingested into aircraft engines. Repairs with significant FOD potential are costly because they result in more labor and expense being required to maintain aircraft and vehicles as well as causing delay costs to be incurred from additional airfield or roadway closures for subsequent repair efforts. It is imperative that repair materials provide a long-lasting operating surface.

This report identifies numerous repair materials and provides guidance for selecting the appropriate product for a range of repair sizes. This information will help repair teams and engineers to select proper materials, mixtures, and repair techniques.

Objective and research approach

The primary objective of this study was to identify and recommend cementitious, rapid-setting repair materials suitable for conducting repairs on PCC airfields from a selection of materials currently on the market and of interest to the U.S. Air Force. The secondary objective of this study was to modify and further develop laboratory selection criteria for evaluating commercial products. Because it is unrealistic to conduct full-scale field trials on all repair materials, these laboratory criteria may facilitate the selection of repair materials in the future as manufacturers continue to improve existing products while concurrently developing new products.

Outline of chapters

Chapter 1 provides an introduction of current challenges facing airfield repair teams and the specific objectives and approach of the project. Chapter 2 presents a background of rapid-setting materials options and requirements of the current project. Chapter 3 describes the laboratory tests. Chapter 4 describes the conclusions and recommendations for future work. References used in preparing this report are provided. Appendices present fact sheets for each rapid-setting product detailed in this report.

2 Background

This chapter describes rapid-setting concrete materials commonly used for airfield and roadway repairs. A review of the literature revealed the general industry acceptance of field-prepared and commercially packaged rapid-setting concretes for roadway and airfield repairs.

Rapid-setting material options

When repair personnel attempt to select a proprietary repair material, they encounter a tremendous number of options. Commercial repair materials are generally categorized as cementitious, asphaltic, or polymeric. Cementitious materials are also referred to as "rigid." For sake of clarity, unless otherwise stated, all materials discussed in this report were cementitious (rigid).

The current study is limited to cementitious products; however, investigations into asphaltic repair materials have also been conducted. Mejias et al. (2010) and Shoenberger (2005) attempted to develop minimum requirements for asphaltic repair materials. At present, no asphaltic prepackaged repair material has been approved for repairs larger than core hole patches on Department of Defense (DOD) airfield pavements due to premature rutting caused by high tire pressures (Mejias et al. 2010). Mejias et al. (2010) provided recommendations to manufacturers to improve product performance for repairs.

Polymer materials are composed of polymer cement mixed with water, coarse aggregate, fine aggregate or sand, and fibers. The polymer cement typically consists of binders, compounds, and mixtures that use epoxy, polyester, vinyl ester or other polymer resin bonds. The cements cure or set through chemical reactions, thermoset bonds, and multiple component binder systems. Advantages of using polymers over traditional portland cement are high strength, increased ductility for some products, and low shrinkage during curing.

In 2008, the U.S. Air Force released an Engineering Technical Letter (ETL) describing a test protocol for selection of polymeric repair materials. This document identified chemical resistance, compressive strength, bond strength, thermal compatibility, and dynamic mechanical properties vs.

temperature for polymeric repair materials. Laboratory test requirements were published in ETL 08-04: *Testing protocol for polymeric spall repair materials* (Air Force Civil Engineering Support Agency (AFCESA) 2008a). The requirements were determined through laboratory and field testing at the U.S. Army Engineer Research and Development Center (ERDC) during 2007 and 2008.

The mechanism by which cementitious products develop their high strength is generally proprietary information. However, the makeup of the materials determines many of the advantages and disadvantages of the products for use as patching materials. The chemical composition of the different products varies principally based on the cementitious component. The general mixture elements of the products are similar to PCC mixtures; however, the products contain rapid-hardening cements, polymers, ordinary portland cement, or a blend of two or more of these cementing components. Blended calcium sulfo-aluminate cement, calcium aluminate cement, gypsum cement, polymers, and ultrafine portland cement are common rapid hardening cements used to produce commercial rapid setting cementitious products. Additional accelerators, water reducers, and admixtures may be present in the final commercial blend. The exact composition of these materials is proprietary in nature, although one can determine the basic components of the materials through material safety data sheets.

In general, the products in this study can be described as belonging to one of three base materials: ultrafine portland cement, magnesium phosphate, and high-alumina. No polymeric materials were included in this study nor were gypsum cements. Blended calcium sulfo-aluminate and calcium aluminate cements may be categorized as high-alumina cements.

Ultrafine portland cement

Ultrafine portland cement materials use a traditional portland cement as the base upon which the paste is developed. The portland cement is ground to an ultrafine level, resulting in a larger available surface area for improved hydration upon mixing with water. This provides the mechanism by which the hydration proceeds more rapidly than in traditional portland cement's chemical reaction.

Magnesium phosphate

Magnesium phosphate materials use a blend of magnesium oxide (MgO) and ammonium dihydrogen phosphate ($NH_4H_2PO_4$) as the base for the paste. Upon mixing with water, these compounds react rapidly, gaining strength and producing large amounts of heat. Historical testing has shown that these products can achieve compressive strengths well in excess of 3,000 psi within 2 hr (Popovics and Rajendran 1988). These materials are generally self-leveling and set quickly, requiring care to prevent flash-setting of large batches.

High alumina

High-alumina materials use monocalcium aluminate ($CaO\text{-}Al_2O_3$) as the primary agent producing rapid strength gain in the paste. These types of cements have also shown ultra-high strengths upon placement compared to conventional PCC pastes made with Type I or II portland cements. Evaluations performed as part of the Corps of Engineers' Repair, Evaluation, Maintenance, and Rehabilitation Research Program (REMR) in 1992 found that these materials generally continue hydration well beyond the 3-hr mark, doubling their strength after 7 days of curing. However, these materials have been shown to produce less strength when subjected to significant moisture and high temperatures (Neville 1975).

Repair material requirements

For this investigation, all repair materials selected were commercially available products marketed to the Department of Defense (DOD) and state departments of transportation (DOTs). The major hydrating component of these materials varied, and the exact chemistry of these materials is recorded in patents, or considered proprietary information, and is not readily available. In general, the materials had a color similar to PCC, could be mixed and placed with portable equipment like PCC, did not pose significant health risks to users, had accelerated hardening characteristics, and yielded a repair that could withstand heavy traffic in short time frames. For both the laboratory and field tests conducted during this study, mixing was performed in accordance with the manufacturers' instructions. Those mixes that did not already contain aggregate were extended using either crushed stone with a 0.75-in. maximum size or pea gravel with a 3/8-in. maximum size depending upon the manufacturer's recommendations to

avoid compatibility issues between the material components and the aggregate.

For materials with magnesium phosphate as the cementing component, crushed limestone aggregates were not used to extend the material. Manufacturers' recommendations precluded the use of limestone due to compatibility issues. For these mixes, either pea gravel or manufacturer provided aggregates were used (Priddy et al. 2007).

Development of draft laboratory test criteria

In order to compare repair materials and evaluate the materials for use in airfield pavement repairs, laboratory testing was necessary to determine the basic material properties of each candidate material. Previous studies have identified numerous tests applicable for repair materials.

In 1991, the Federal Highway Administration (FHWA) identified compressive strength, flexural strength, modulus of elasticity, Poisson ratio, bond strength, thermal compatibility, length change, resistance to freezing and thawing, and resistance to abrasion and scaling as important performance characteristics for repair materials (Wilson et al. 1999). Another study recommended testing compressive and flexural strength, set time, and shear bond (Beer et al. 1984) to evaluate material performance. Additionally, numerous products were evaluated under the REMR Program in 1999. Twelve cementitious and polymeric materials were evaluated under the REMR Program to identify applicable laboratory tests and minimum test results for use in selecting repair materials. Testing performed under this program identified compressive strength, modulus of elasticity, shrinkage, creep, thermal compatibility, and flexural strength as applicable tests for repair materials. Out of these tests, required values were recommended for compressive strength, tensile strength, and drying shrinkage (Vaysburd et al. 1999).

In 2006, the U.S. Air Force released a draft ETL identifying compressive strength, bond strength, thermal compatibility, shrinkage potential, and freeze-thaw resistance as the most important characteristics to evaluate in comparing cementitious, rapid-setting materials for spall repairs. The requirements set forth in this ETL were based on laboratory and field testing conducted during 2005 and 2006 by personnel at ERDC. Results from the tests were compared to requirements produced under the REMR (1992; 1999) Program (U.S. Army Engineer Waterways Experiment

Station 1992; Vaysburd et al. 1999). Table 1 presents the material tests and required properties for this draft ETL.

Table 1. Draft test result requirements ETL 08-02 (2006 Draft).

Property	ASTM	Requirement
Compressive strength	C 39	≥ 3,000 psi Test at ages of 2 hr and 1 day
Bond strength	C 882	≥ 850 psi (repair bonding to OPC mortar) ≥ 1,000 psi (repair material bonding to repair material) Test at age of 1 day
Modulus of elasticity	C 469	≤ 4×10^6 psi Test at age of 3 days
Coefficient of thermal expansion	C 531	≤ 7×10^{-6} in./in./°F Test begins at age of 3 days
Shrinkage potential	C 1581	≤ 40 microstrain at 14 days and No cracking at 28 days Test begins at time of casting
Freeze-thaw resistance	C 666	No requirement at this time[a] Test begins at age of 3 days

[a] A possible requirement designed to eliminate materials that are extremely susceptible to freeze-thaw damage would be ≤ 50% loss in relative dynamic modulus of elasticity after 50 cycles.

Selected material investigations

Laboratory and field tests of cementitious repair materials conducted from 2006 through 2010 at ERDC were used in the current investigation. Additional laboratory and field tests conducted at the Air Force Research Laboratory (AFRL) during 2007 were also considered in this investigation, as they were conducted in accordance with the requirements of ETL 08-02 (AFCESA 2008a). Finally, tests conducted on cementitious repair materials at Missouri University for Science and Technology (MST) in 2009-2010 were also identified for use in this investigation. Although these tests were conducted for roadway repair selection criteria, they were also conducted in accordance with the requirements of Air Force ETL 08-02 (AFCESA 2008a). The following sections describe the work conducted from 2006 to 2010. Fact sheets regarding test results of each product are presented in the appendices.

Laboratory tests 2006-2008

Table 2 presents a list of products tested and the results of the tests performed at ERDC and at AFRL from 2006 through 2008. Based on laboratory test results, field testing of selected products was conducted

during that period of time at ERDC and at AFRL for a variety of common permanent repair activities including spall repair, small patches, large patches, and slab replacement. Temporary repair activities of interest to the agencies during that time, including small and large crater repair and expeditionary spall repairs, were also tested. For clarity, each repair type is briefly summarized in the following sections.

Table 2. 2006-2008 Summary of products, results, and recommendation by agency.

No.	Year	Product	Manufacturer	Result	Recommendation	Agency
1	2007	ABC Cement	ABC	Fail	Not approved	ERDC
2	2007	Express Repair	Tamms	Fail	Not approved	ERDC
3	2007	Futura 15	W.R. Meadows, Inc.	Fail	Not approved	AFRL
4	2007	HD-50 Rapid Set	Dayton Superior	Fail	Expeditionary spall repairs	AFRL
5	2007	Pavemend 15	Ceratech, Inc.	Fail	Expeditionary spall repairs	AFRL
6	2007	Pavemend SL	Ceratech, Inc.	Pass	Expeditionary spall repairs	ERDC
7	2007	Pavemend SLQ	Ceratech, Inc.	Fail	Spall repair, small patches	ERDC
8	2007	Pavemend TR	Ceratech, Inc.	Fail	Expeditionary spall repairs	AFRL
9	2007	Pavemend VR	Ceratech, Inc.	Fail	Not approved	AFRL
10	2007	PavePatch 3000	Conspec Co.	Fail	Not approved	AFRL
11	2007	Premium Patch 200	Pre-Blend Products, Inc.	Fail	Expeditionary spall repairs	AFRL
12	2007	Rapid Set Concrete Mix	CTS Cement	Pass	Spall repairs, small patches, large patches, slab replacement, small and large crater repair	ERDC
13	2007	Rapid Set DOT Mix	Degussa	Pass	Expeditionary spall repairs	AFRL
14	2007	Set 45HW	Degussa	Fail	Spall repair, small patches and large patches, and small crater repair	ERDC
15	2007	SikaQuick 2500	Sika Corporation	Pass	Expeditionary spall repairs	AFRL
16	2007	Thoroc 10-60	Degussa	Pass	Spall repair, small patches, large patches, and slab replacement	ERDC
17	2007	Thoroc 10-61	Degussa	Pass	Expeditionary spall repairs	AFRL
18	2007	Thoroc 10-61	Degussa	Pass	Spall repair, small patches, large patches, slab replacement, small and large crater repair	ERDC
19	2007	Ultimax Concrete Mix	Ultimax	Fail	Spall repair, small patches, large patches, slab replacement, and small and large crater repair	ERDC
20	2007	Versaspeed	Euclid Chemical Co.	Fail	Expeditionary spall repairs	AFRL

Permanent repairs

Spall repair. A spall repair is a repair to correct cracking, breaking, chipping, or fraying of a concrete slab along an edge or at a corner. A spall repair may be a full-depth repair (entire slab depth is removed and replaced) or a partial-depth repair (some slab depth is removed and replaced). Depending on damaged surface area, a spall repair usually requires a small patch (surface area of less than 5 ft^2).

Small patch. A small patch is a repair made to replace less than 5 ft^2 of damaged pavement. A small patch is not limited to spall repair as it may replace pavement damaged within a slab, such as a small utility cut.

Large patch. A large patch is a repair made to replace more than 5 ft^2 of damaged pavement. A large patch may replace pavement damaged within a slab, such as a large utility cut.

Slab replacement. A slab replacement is a repair requiring an entire slab to be removed and replaced.

Temporary repairs

Crater repair. Crater repair is a temporary repair activity that may be conducted during times of war. A hole within a slab or across several slabs may occur due to a munition blast. A crater differs from a spall in that the damage extends through the surface of the pavement into the substrate. A small crater consists of craters with an apparent diameter less than 15 ft, while craters with diameters in excess of this are considered large craters. Small craters are generally repaired using a small or large patch within or across slabs. A large crater repair is generally repaired using a large patch, full-slab replacement, or multiple slab replacement if the crater extends across multiple slabs. Because of mission requirements, the materials investigated in these studies must be mixed and placed using standard concrete mixers for either small or large crater repairs. Repairs meeting these criteria were specially noted as applicable for crater repair.

Expeditionary spall repair. An expeditionary spall repair is a spall repair conducted to temporarily return an airfield to service. The repairs are not expected to perform for long durations of time. Special testing was conducted with numerous products specifically for this type repair. Many of the materials identified as acceptable for expeditionary spall repair did

not meet ETL 08-02 requirements (AFCESA 2008a). Because of this, materials identified for this repair type were identified separately from the common repair types of spall repair and small patch.

As seen in the table, some products were evaluated by both labs including Pavemend TR and Thoroc 10-61. Fact sheets were created summarizing test results as compared to ETL 08-02.(AFCESA 2008a). These sheets also contain material mixing/handling instructions for each product (Appendices A and B).

During 2006 and 2007, laboratory investigations of 10 cementitious, rapid-setting materials were conducted at ERDC in Vicksburg, MS. Due to the limited nature of the project, only compressive strength, set time, and slant shear testing were conducted (Priddy et al. 2007).

Following laboratory testing, limited field testing was conducted for all products, except ABC Cement, during July 2007. ABC Cement underwent a formulation change following material tests. Thus, retesting ABC Cement under laboratory conditions was recommended prior to field testing. Full-depth patches were constructed consisting of 6-in. caps of cementitious materials over 8 in. of compacted crushed gravel. Traffic tests were conducted using a load cart equipped with an F-15E wheel loaded to approximately 35,235 lb. The tire pressure was maintained near 325 psi. Each repair material was trafficked to failure, anticipated to occur after 100 passes.

During field testing of Pavemend SL, early failure resulted in material reformulation by the vendor. Following this test, additional testing was recommended for this material. Pavemend SLQ also experienced an early failure after 96 passes. Following traffic, the repair was removed to investigate the subgrade condition. It was determined that the subgrade had been weakened due to rainy conditions just prior to the repair. The repair was repeated resulting in more than 1,000 passes. The remaining materials failed after approximately 700 passes.

As shown in Table 2, although some materials did not meet minimum recommendations for compressive strength and slant shear results (“failed” in the table), they were approved for use such as Pavemend SLQ, Set 45 HW, and Ultimax Concrete. This approval was based on good field test results shown in Table 3 (Priddy et al. 2007).

Table 3. Summary of traffic tests on cementitious materials 2007.

Repair	Capping Material	Cap Thickness, in.	Failure Mode	Failure Detail	Passes to Failure
1	Express Repair	6	FOD	High-severity shattered slab	224
2	Pavemend SL	6	Curing	High-severity shattered slab/ uncured material	16
3a	Pavemend SLQ	6	Subgrade	Subgrade failure	96
3b	Pavemend SLQ	6	FOD	High-severity joint spalls	1,344
4	Rapid Set	6	FOD	High-severity joint spalls	688
5	Set 45 HW	6	FOD	High-severity joint spalls	704
6	ThoRoc 10-60	6	FOD	High-severity joint spalls	704
7	ThoRoc 10-61	6	FOD	High-severity joint spalls	720
8	Ultimax Concrete	6	FOD	High-severity joint spalls	720
9	ABC Cement	Not field tested			

During the same time period, the Air Force Research Laboratory (AFRL) tested 11 cementitious, rapid-setting repair materials. AFRL conducted compressive strength, splitting tensile strength, flexural strength, modulus of elasticity, and slant shear tests (Hammons and Saeed 2010). Limited data from these tests are presented in the Appendix A. Following laboratory testing, field testing was conducted. Results of the field testing indicated, although most of the materials did not meet minimum requirements based of ETL 08-02 (AFCESA 2008a) for compressive strength and bond, that some of the repair materials were adequate for expeditionary spall repairs. These expeditionary spall repairs were required to withstand 1,500 passes of simulated F-15E aircraft traffic. The materials selected for expedient repairs are detailed in Table 2 and in ETL 07-08 (AFCESA 2007).

2006-2008 Results

Based on laboratory and field results, several products were recommended for airfield pavement repairs. However, not all materials were suitable for large repairs or full-slab replacement due to volume limitations for mixing. For example, Pavemend SLQ is mixed in 5-gal buckets using drills and paddles. Due to the fast set time, numerous small batches would be required to complete a large volume repair. With short time frames for repair, the batches would have to be mixed simultaneously. In this situation, another repair material might be more appropriate. The recommen-

dations for repair type based on laboratory and field test results during this time frame and based on mixing limitations are presented in Table 2.

ETL modifications

Based upon laboratory and field tests at ERDC in 2007 and 2008, it was determined that expansion of the repair materials might be a concern. Three large repairs performed during the summer and fall of 2007 using Pavemend SLQ experienced significant volume changes 6 to 9 months after placement, as indicated by swelling and cracking of the repairs and cracking of the parent slabs in which the patches were placed (Figure 1). Initial laboratory and field tests indicated Pavemend SLQ was suitable for spall repair and small patches. Results of petrographic examination and analysis of samples collected from each repair indicated that unhydrated materials remained in samples collected from the field tests. No other repair material tested during this time experienced this problem. Additionally, expansion testing was conducted in the laboratory according to the American Society for Testing and Materials (ASTM) C 157 (ASTM 2008c) to determine the percent expansion of the repair material under different environmental conditions. Based on expansion limits for traditional PCC, it was determined that the cementitious repair material

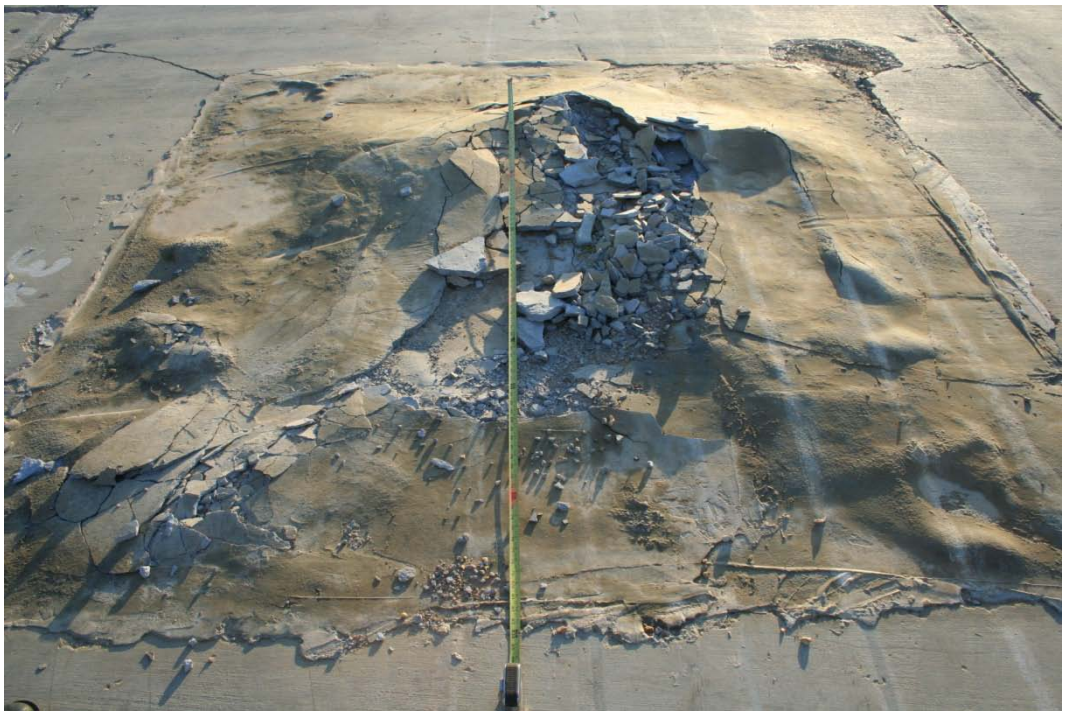

Figure 1. Pavemend SLQ surface after expansion.

Table 4. Published cementitious test result requirements for ETL 08-02.

Property	ASTM	Requirement
Compressive strength	C 39	≥ 3,000 psi at age of 2 hr. ≥ 5,000 psi at age of 1 day.
Flexural strength	C 78	≥ 350 psi at ages of 2 hr and 1 day.
Bond strength	C 882	≥ 850 psi (repair bonding to OPC mortar) at age of 1 day. ≥ 1,000 psi (repair material bonding to repair material) at age of 1 day.
Modulus of elasticity	C 469	≤ 3 x 10^6 psi at age of 2 hr. ≤ 4 x 10^6 psi at age of 3 days.
Volumetric expansion	C 531	≤ 7 x 10^{-6} in./in./°F begin at age of 3 days.
	C 157	< 0.03% begins at age of 4 days.
Shrinkage potential	C 1581	≤ 40 microstrain at age of 14 days and No cracking at 28 days Test begins at time of casting.
Freeze-thaw resistance	C 666	Test begins at age of 3 days. No requirement at this time[a].
Time of setting	C 191	Test begins immediately. No requirement at this time[b].

[a] Depending on future testing, a possible freeze-thaw resistance requirement would be ≤ 50% loss in relative dynamic modulus of elasticity after 50 cycles.

[b] Report initial and final set times in minutes.

should not expand more than 0.03 percent. Thus, an expansion test was added to the testing protocol for cementitious repair materials in 2008 (Priddy et al. 2008).

This ETL was further modified in 2008 to add flexural strength requirements based on compressive strength correlations. Additionally, it was requested that time-of-set tests be conducted, although no criterion was set for this property. Additional test result requirements were added for compressive strength (1-day strength ≥ 5,000 psi) and modulus of elasticity (≤4 x 10^6 psi) based on normal PCC requirements. The modified ETL was published as ETL 08-02: *Testing protocol for rigid spall repair materials* in 2008 (AFCESA 2008).

Material testing 2008-2009

In 2008 and 2009, cementitious, rapid-setting materials were retested following modified ETL 08-02 (AFCESA 2008a) protocol described in the previous section. Pavemend SLQ, ABC Cement, Pavemend TR, and Rapid Set Concrete Mix®, were tested at ERDC. DOTLine, Mainline, and Great

White were tested by a Corps of Engineers certified laboratory under contract to ERDC.

Following laboratory testing, limited field testing was conducted on Pavemend SLQ, ABC Cement, Pavemend TR, Rapid Set Concrete Mix, Great White, and DOTLine. Traffic tests were conducted using a load cart fitted with an F-15E wheel loaded to approximately 35,235 lb. Tire pressure was maintained near 325 psi. Full-depth patches were constructed consisting of 6-in. cementitious caps over 8 in. of compacted crushed gravel. Each repair material was trafficked to failure.

Although field testing was conducted using Pavemend SL during 2007, additional field tests were conducted in 2008 to evaluate a new formulation of Pavemend SL. Results of field testing resulted in only 144 passes of the load cart prior to failing. This repair's passes-to-failure were much lower than other products that were achieving approximately 700 passes for the same cap thickness prior to failure.

Results of field testing conducted during 2008 also determined that Pavemend TR required longer than 3 hr of cure prior to aircraft trafficking. A repeat repair was conducted on the material with a 4-hr cure with good trafficking results. This repair consisted of 9 in. of Pavemend TR over 24 in. of compacted clay gravel. This repair withstood 5,000 passes of simulated F-15E traffic without failing.

Two additional repairs were conducted and traffic tested using the F-15E load cart. ABC Cement was mixed and placed using a prototype proportional mixer. This repair consisted of a 9-in. cementitious cap over approximately 24 in. of compacted well-graded limestone. Great White was mixed using a standard proportional mixer to place a 9-in. cap of repair material over a limestone base in the same repair geometry of the ABC repair. Both repairs withstood more than 2,000 passes of F-15E traffic with only limited spalling of the repair edges.

2008-2009 Results

Based on laboratory and field results from the 2008-2009 testing, several products were recommended for airfield pavement repairs. As noted previously, not all materials were suitable for large repairs or full-slab replacement due to volume limitations for mixing. For example, Pavemend SL, Pavemend SLQ, DOTLine, and TR are typically mixed in 5-gal buckets using

drill and paddle. Attempts to mix DOTLine in larger volumes resulted in flash-set of the material. Pavemend TR was successfully mixed using a 1-yd^3 horizontal shaft mixer. However, build-up of material within the mixer was undesirable. Additionally, Pavemend TR was difficult to finish resulting in a rough surface appearance (Figure 2). These repair materials are more appropriate for small patches that are better suited for bucket mixing limited volumes of material. Pavemend TR also requires curing of at least 4 hr prior to traffic compared to only 2 to 3 hr for the other materials.

Figure 2. Pavemend TR surface.

Materials such as Great White and Rapid Set Concrete Mix are appropriate when larger mix volumes are necessary and are best suited for proportional mixers. The use of a proportional mixer requires advanced calibration of the equipment with the material, thus they should only be used when experienced operators have been trained on using the material with the mixer. ABC Cement was suited for various sized repairs and could be mixed in a variety of volumes, but the material required the use of liquid admixtures instead of water. Rapid Set Concrete Mix could be mixed in small and large volumes with various pieces of equipment. The recommendation for repair type is also presented in Table 5.

Table 5. 2008-2009 Summary of products, results, and recommendation by agency.

No.	Product	Manufacturer	Result	Recommendation	Agency
1	Rapid Set Concrete Mix	CTS Cement	Pass	Spall repair, small patches, large patches, full-slab replacement, small and large crater repair	ERDC
2	Pavemend SLQ	Ceratech, Inc.	Fail	Spall repair, Small patches	ERDC
3	Pavemend SL	Ceratach, Inc.	Fail	Not recommended	ERDC
3	ABC Cement	ABC	Pass	Spall repair, small patches, large patches, full-slab replacement, small crater repair	ERDC
4	DOTLine	Ceratech, Inc.	Fail	Not approved	ERDC*
5	Mainline	Ceratech, Inc.	Fail	Not approved	ERDC*
6	Great White	Ceratech, Inc.	Fail	Slab replacement	ERDC*
7	Pavemend TR	Ceratech, Inc.	Fail	Approved with 4 hr cure. Spall repair, small patches, and large patches	ERDC

As shown in Table 5, although some materials such as Pavemend SLQ, Great White, and Pavemend TR (with 4 hr of cure) did not meet minimum recommendations for compressive strength and slant shear results ("fail" in the table), they were initially approved for use. This approval was based on good field test results shown in Table 6. Due to low pass-to-failure results for Pavemend SL and DOTLine, these materials were not recommended for airfield repairs. DOTLine also failed shrinkage potential laboratory tests. Mainline was not field tested; however, laboratory results do not indicate that this repair material would be suitable for airfield repair. Laboratory test results are presented in Appendices C and D.

Laboratory tests 2009-2010

During 2010, ERDC conducted tests, in accordance with requirements of ETL 08-02 (AFCESA 2008a), on several products including repeat testing on ABC Cement, PavePatch 3000, Set 45HW, Rapid Set Concrete Mix, and Premium Patch 200. Results for materials tested during this period of investigation are provided in Table 7. Not all tests required by the ETL were conducted when initial results indicated failure of the materials; specifically, bond strength, volumetric expansion, and shrinkage potential were not tested. Field validation tests were not conducted on the materials tested during this time. Several of the materials had been field tested

Table 6. Summary of traffic tests on cementitious materials 2008-2009.

Repair	Capping Material	Cap Thickness, in.	Failure Mode	Failure Detail	Passes To Failure
1	Rapid Set Concrete Mix	6	FOD	High-severity joint/corner spalls	784
2	Pavemend SLQ	6	FOD	High-severity joint spalls	455
3	DOTLine	6	FOD	High-severity joint spalls	224
4	Pavemend TR	6	Curing	Uncured material	40
5	Pavemend SL	6	FOD	High-severity joint spalls	144
6	Mainline	6	Not tested		
7	Great White	9	No failure	No failure	2,000
8	ABC Cement	9	FOD	High-severity joint spalls	2,000
9	Pavemend TR	9	No failure	No failure	5,000

Table 7. 2009-2010 Summary of products, results, and recommendation by agency.

No.	Product	Manufacturer	Result	Recommendation	Agency
1	Speedcrete 2028	Euclid Chemical	Fail	Not recommended	MST
2	Set 45HW	BASF Building Solutions	Fail	Spall repair, small patches and large patches, and small crater repair	MST
3	ABC Cement	ABC	Fail	Small patches, large patches, full-slab replacement, small crater repair	MST
4	HD-50 Rapid Set	Dayton Superior	Fail	Expeditionary spall repairs, small patches, spall repair	MST
5	PavePatch 3000	Conspec Co.	Fail	Expeditionary spall repairs, small patches, spall repair	MST
6	Quikrete Fast Set DOT Mix	Quikcrete	Pass	Expeditionary spall repairs, small patches, spall repair	MST
7	Rapid Set Concrete Mix	CTS Cement	Pass	Spall repairs, small patches, large patches, slab replacement, small and large crater repair	MST
8	Rapid Set Concrete Mix	CTS Cement	Pass	Spall repairs, small patches, large patches, slab replacement, small and large crater repair	ERDC[a]
9	HD-50	Dayton Superior	Pass	Expeditionary spall repairs, small patches, spall repair	ERDC[a]
10	Premium Patch 200	Pre-Blend Products, Inc.	Pass	Expeditionary spall repairs, small patches, spall repair	ERDC[a]
12	Fastrac Concrete Mix	Western Material & Design, LLC	Fail	Not recommended	ERDC[a]

[a] Material tested by Burns, Cooley, Dennis, Inc.

previously, including Set 45HW, ABC Cement, HD-50 Rapid Set, and Rapid Set Concrete Mix. Fact sheets detailing those test results are presented in the Appendices E and F.

Based on results of the laboratory tests performed, only two of the materials tested, Quikcrete Fast Set DOT Mix and Rapid Set Concrete Mix, met the minimum standards set forth in the ETL. Although no field testing was conducted on Quikcrete Fast Set DOT Mix, its high early compressive strengths indicate that this material may be suitable for expeditionary spall repairs, spall repairs, and small patches. Because there was no field test data for placement or traffic data, this material was not recommended for large patches or crater repair. Recommendations for use of Rapid Set Concrete Mix, based on the prior testing detailed in previous sections, were not changed as a result of retesting.

Two materials, Speedcrete and Fastrac Concrete Mix, tested during this time were not recommended for use. Speedcrete was not recommended because of its low compressive strength at 2 hr and the lack of field placement and trafficking data for the material. Fastrac Concrete Mix was not recommended because it was too difficult to mix and place without the addition of citric acid. However, when citric acid was added, the material failed to develop adequate compressive strength as shown in the fact sheets in Appendix E. The remaining materials tested in 2009 through 2010 did not meet minimum test requirements as detailed in the current version of ETL 08-02 (AFCESA 2008a). The recommendations presented in Table 7 are based on results of laboratory testing and field test results conducted in previous years by ERDC or AFRL as discussed in previous sections.

Shortfalls of previous research

Based on review of the previous studies and requirements of ETL 08-02, few repair materials met all current ETL requirements. Despite not meeting minimum laboratory performance criteria, several cementitious repair materials were initially recommended for use based on good field performance. This indicated that a review of the test requirements compared to field results was needed. Additionally, because some materials were only suitable for a specific size (small or large) repair, a general approval of the material as a repair material was not appropriate. Repair materials should be approved for the different volume applications (spall repair, small

patching, large patching, or full-slab replacement) or repair types (temporary vs. permanent) to which they are best suited.

The following chapters detail the test procedures used for the cementitious materials, compare test results of the different products, propose changes to the current requirements, and provide recommendations for use of repair materials by repair size and type.

3 Cementitious Material Laboratory Test Descriptions

This section summarizes various material characterization parameters and the various test methods employed to evaluate the cementitious, rapid-setting materials addressed in this study.

Strength

For determining suitability of a pavement for opening to traffic, the strength criterion is often the most stringent requirement, especially for rapid-setting concretes. For highway and airfield agencies, strength criterion is usually reported as either flexural strength or compressive strength. Although flexural strength can be correlated to compressive strength, current criteria may vary in the test used or require that both be reported. The cementitious, rapid-setting repair materials must meet or exceed the criterion set for strength prior to returning the pavement to service.

Compressive strength

Minimum compressive strength criterion is important for ensuring that the concrete will not crush easily under wheel loads or under stresses caused by environmentally induced pavement movements. Compressive strength testing was accomplished in accordance with ASTM C 39 procedures (ASTM 2005). The compressive strength of concrete mixtures was evaluated by testing 4-in. × 8-in. cylinders. Methods of curing and capping the specimens are addressed in a later section. The duration of curing, prior to testing, was either 2 hr or 24 hr. The curing duration was established as the time elapsed from final finishing to testing of a specimen, not the time elapsed from initial set of the material to the time of testing. Results were reported as maximum compressive stress (psi), which equals the maximum applied load divided by the specimen's initial, unloaded cross-sectional area. Figure 3 shows a compressive specimen after testing.

Flexural strength

In addition to resisting crushing forces, the cementitious material must also resist bending forces or flexure. Flexural strength testing was

Figure 3. Compressive specimen after test.

conducted in accordance to ASTM C 78 procedures (ASTM 1994; ASTM 2008b). The test specimens were rectangular beams with typical dimensions of 6-in. × 6-in. × 18-in. long. Tests were conducted on the specimens with an unsupported span equal (within 2 percent variation) to three times its depth. Loading was applied at third-points of the span. Figure 4 shows beam specimens during curing. The beams were cured the same as previously described for the cylinders. Figure 5 shows a cured beam undergoing testing. Results were reported as the ultimate tensile stress achieved before failure, also known as the modulus of rupture (psi).

Bond strength

Bond strength is important for ensuring that the material used for spall repair will adhere to the damaged pavement material and not become easily dislodged under trafficking. Bond strength testing was conducted in accordance with the requirements of ASTM C882 (2005a). This procedure involves the preparation of specimens in 3-in. × 6-in. cylinder molds. A bond line was produced at approximately 30 deg from vertical by first casting wedge-shaped dummy sections of either ordinary portland cement (OPC) mortar or the repair material itself in the cylinder molds. After

Figure 4. Flexural beams.

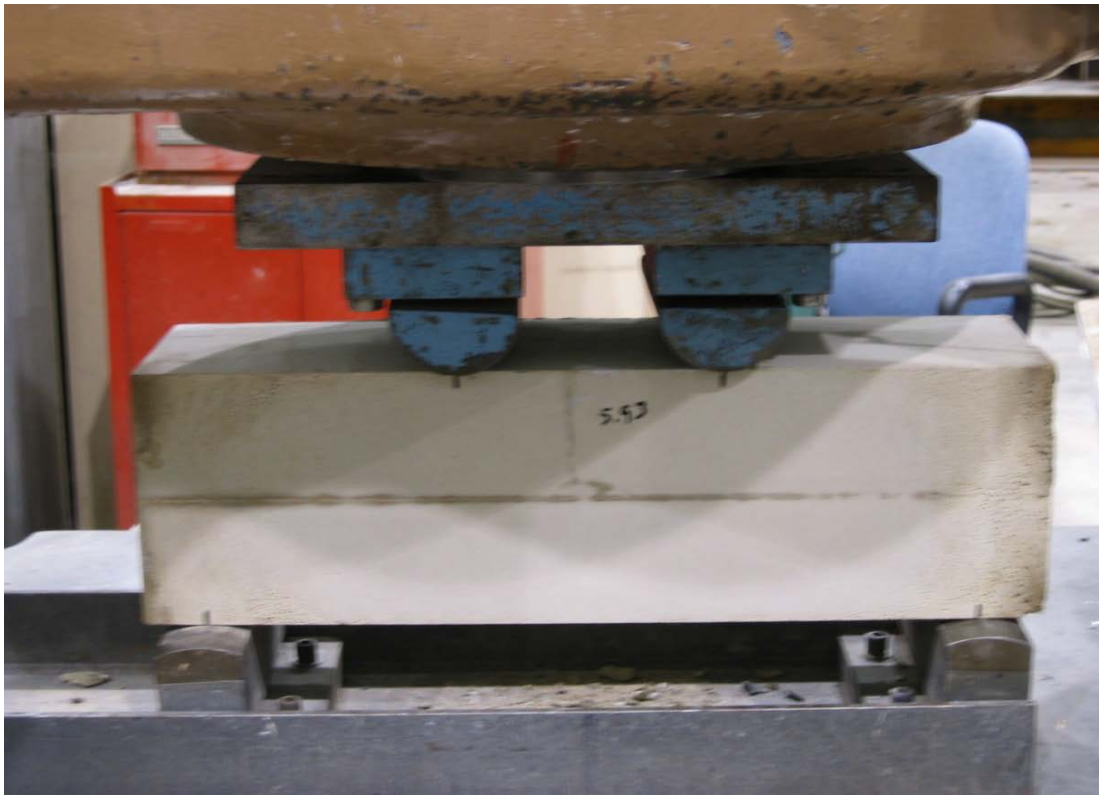

Figure 5. Flexural beams undergoing test.

curing these wedge-shaped sections, the repair material was placed on top of the dummy section in the mold and cured for 1 day. Curing and capping methods for the cylinders are addressed in a later section. The composite cylinder, produced with repair material bonded either to OPC mortar or to itself, was tested in compression (Figure 6). Results were reported as maximum bond stress (psi), which was calculated as maximum axial load divided by the area of the elliptical bonding surface.

Figure 6. Slant shear sample undergoing test.

Time of setting

Working time, for materials considered in this study, was defined as the elapsed time between the initial contact of water with the repair material and the initial set of the material. Because of the short working times associated with rapid-setting cementitious materials, it becomes an important consideration in selecting a material to accomplish a repair. Testing was accomplished in accordance with ASTM 403/C 403M (ASTM 2006). For this testing, a properly proportioned paste of the subject material is mixed to normal consistency and molded. Periodic penetration tests are performed on this paste by forcing a standardized needle downward into the paste and recording the time required for the needle to penetrate 1 in. into this paste. The penetration resistance was calculated by dividing the

recorded force by the bearing area of the needle. The initial time of setting was the time elapsed between the initial contact of cement and water and the time when the penetration resistance equaled 500 psi. The final time of setting was the time elapsed between initial contact of the cement and water and the time when the penetration resistance equaled 4,000 psi. Time of setting was reported in minutes. Testing began immediately after the paste is mixed due to fast set times associated with these repair materials.

Shrinkage

Shrinkage potential includes drying shrinkage, thermal shrinkage, and autogenous shrinkage, all of which occur during hydration. Shrinkage potential is important because repair materials that shrink excessively are more prone to bonding problems and to shrinkage-related cracking.

Shrinkage was measured using a restraining ring device, in accordance with ASTM C 1581 (ASTM 2004a). While this procedure was slightly more involved than the traditional linear bar shrinkage test, which can be accomplished in conjunction with the coefficient of thermal expansion test ASTM C 531 (ASTM 2000, 2005b), the use of restraint was an attempt to capture all components of shrinkage previously listed. The linear bar shrinkage test is limited to measuring only drying shrinkage. The restraining ring was constructed with structural steel pipe with a wall thickness of 0.5 in., an outside diameter of 13 in., and a height of 6 in. The concrete mix was cast on the outside of the restraining ring in a manner that produced a material ring with a height of 6 in. and a wall thickness of 1-1/2 in. The repair ring was moist cured at 73.5°F for 24 hr. Then, the outer form that was used to shape the repair ring was removed and the top of the repair ring was sealed so that all drying occurs on the outer circumference of the repair ring. The restraining ring stayed in place during the entire test. The repair ring then cured in an environment with 50 percent relative humidity and a temperature of 73.5°F for 28 days during which the ring was monitored for cracking and the circumferential strain on the inside of the restraining ring was measured using foil strain gages. Results reported included ring strain at the end of moist curing, age at the time of first crack (if cracking occurs), and ring strain at either the age at the time of first crack or 28 days if cracking never occurs. The ages were computed from the time of casting the repair ring. Figure 7 presents a sample undergoing strain measurement. Figure 8 presents a sample that has cracked prior to 28 days.

Figure 7. Ring shrinkage sample prior to cracking.

Figure 8. Ring shrinkage sample after cracking.

Modulus of elasticity

Modulus of elasticity is important because a cementitious repair material should not have stiffness significantly different than the parent material onto which it is applied. With a higher stiffness, the repair material would assume higher stresses under wheel loading and pavement movement. In terms of bonding, significant differences in stiffness would change the amount of strain/deflection between the parent slab and repair material. This would be particularly true in the tension zone where differential deflections would lead to patches exceeding the parent materials bond strengths resulting in debonding.

Modulus of elasticity testing (Figure 9) was accomplished in accordance with ASTM C 469 procedures (ASTM 2010a). Cylinders were either 3 in. × 6 in. or 6 in. × 12 in. In this method, a bonded or unbonded sensing device was attached to the cylinder at mid-height for the purpose of measuring vertical deformation. The gage length of the measurement was at least three times the maximum aggregate size and not more than one-half the specimen height. The modulus of elasticity (with units of psi) was calculated as change in stress divided by change in strain, where strain was calculated as

Figure 9. Sample undergoing modulus of elasticity testing.

vertical deformation divided by the gage length. The calculation, as specified in ASTM C 469 (ASTM 2002), produced a chord modulus of elasticity where the cord line is drawn between the stress at 50 milistrain and the strain at 40 percent of the compressive strength. Tests were conducted after the specimens had cured 2 hr and on other specimens after 3 days. Curing and capping methods for cylinders are addressed in later sections.

Volumetric expansion or contraction

Excessive expansion and contraction of material used in a spall repair, due to either internal or external forces, will result in a loss of bond to the parent material. Additionally, if the spall repair is large, excessive expansion of the repair material can result in the deterioration of the surrounding pavements.

Coefficient of thermal expansion

The material's coefficient of thermal expansion is important because a repair material with a coefficient of thermal expansion that is significantly greater than the parent material would experience greater volume changes with changes in temperature (volumetric expansion due to externally applied forces). The difference in movements for the repair material versus the parent material would tend to deteriorate the bond between the two materials. Coefficient of thermal expansion testing was accomplished in accordance with ASTM C 531 procedures (ASTM 2000, 2005b). These procedures involved the production of prismatic bars (1 in. × 1 in. × 10 in.) with metal studs on each end. The studs facilitated length measurements. The lengths of the bars were measured at both 73°F and 210°F. The coefficient of thermal expansion was calculated as strain per degree F, with units of in./in./°F. Testing began after the prisms cured 3 days.

Length change

Because volumetric expansion of repair materials can result from causes other than applied force or temperature changes, testing for expansion due to internal forces was accomplished according to ASTM C 157 procedures (ASTM 2008c). If a spall repair material experienced length changes greater than +0.03% (expansion) or less than -0.04 percent (contraction), this may have resulted in deterioration of the bond with the parent material and deterioration of the parent material itself. Following ASTM C 157 procedures, test specimens were prismatic bars with dimensions based on

maximum aggregate size. For repair materials with maximum aggregate size of 0.75 in., prismatic bars were 3 in. × 3 in. × 11.25 in. with metal studs on each end. The studs facilitated length measurements. The bars were then cured in either water at 73°F or air at 73°F with a 50 percent relative humidity. Readings were taken during curing after 4, 7, 14, and 28 days and after 8, 16, 32, and 64 weeks. Specimens were removed from the molds 2.5 to 2.75 hr after the addition of mixing water. Initial observations of length were made 3 to 3.25 hr after the addition of mixing water according to ASTM C 928 (ASTM 2009) standard. The length change at each age was calculated as a percentage (change in length/original length × 100 percent).

Methods of curing and capping

Although the curing and capping of laboratory specimens are not tests, they are important considerations for purposes of accomplishing accurate and consistent testing.

Curing

Curing affects all tests previously described, but note that the restraining ring shrinkage test involves specific curing conditions that must be met. For the other tests, curing optimally reflected the type of curing that will be accomplished in field placements. It also reflected the type of curing that was recommended by the repair material's manufacturer. When in doubt about the anticipated field procedures, materials were air cured at room temperature and 50 percent relative humidity to impose less than optimal, but realistic, curing conditions. Curing conditions were reported with the test results. To reflect field performance, curing durations for this report, unless specifically noted, were the time elapsed from the final finishing of a test specimen to the time of testing, not the time elapsed from the initial set of the material to the time of testing.

Capping

Capping affects compressive strength, bond strength, and modulus of elasticity testing. Capping was necessary to provide flat ends that were perpendicular to the sides of the cylinders to ensure proper loading during testing. Capping was accomplished with either bonded materials (ASTM C 617)(ASTM 2010b) or unbonded pad caps (ASTM C 1231) (ASTM 2008a). For this protocol, compressive strength and bond strength testing were accomplished with unbonded pad caps. Modulus of elasticity testing

required the use of bonded caps. Capping methods were also reported with the test results.

Replicates

Three replicates were required for each of the tests described in this report. The average result, calculated from the three replicates, was compared to the requirements presented in the ETLs. The average of only two replicates was not acceptable.

4 Results and Discussion

Since the development of ETL 08-02 (AFCESA 2008a), the American Society for Testing and Materials approved a standard for rapid-setting cementitious materials. ASTM C 928 (ASTM 2009) defines three types of packaged, dry, rapid-hardening concretes/mortars as R1, R2, and R3. This standard also provides performance requirements for length change, consistency, and scaling resistance. Table 8 presents the performance requirements required by the standard.

Table 8. ASTM C928 requirements for cementitious, rapid-setting materials.

	3 h	1 day	7 days	28 days
Compressive Strength, min, MPa [psi]				
R1 concrete or mortar	3.5 [500]	14 [2000]	28 [4000]	[B]
R2 concrete or mortar	7.0 [1000]	21 [3000]	28 [4000]	[B]
R3 concrete or mortar	21 [3000]	35 [5000]	35 [5000]	[B]
Bond strength, min, MPa [psi]				
R1, R2 and R3 concrete or mortar	—	7 [1000]	10 [1500]	—
Length change, based on length at 3 h, max, %				
R1, R2, and R3 concrete or mortar	allowable increase after 28 days in water			+0.15
	allowable decrease after 28 days in air			–0.15
Consistency of concrete or mortar[C]			concrete slump, min, mm [in.]	Flow of mortar, min, %
R1 consistency after 15 min after addition of mixing liquid			75 [3]	100
R2 and R3 consistency at 5 min after addition of mixing liquid			75 [3]	100
Scaling resistance to deicing chemicals after 25 cycles of freezing and thawing				
Concrete, max visual rating			2.5	
Mortar, max scaled material[D]			5 kg/m^2 [1 lb/ft^2]	

[A] It is recognized that other characteristics of rapid-hardening concrete repair materials might need consideration. Such characteristics might be necessary in some environments and applications; however, to impose specification limits on all products is considered beyond the scope of this specification. Optional considerations with suggested methods of test may include tests for the following:

Time of setting	Test Method C403/C403M
Flexural strength	Test Method C78
Freeze thaw	Test Method C666/C666M, Procedure A
Sulfate expansion	Test Method C1012

[B] The strength at 28 days shall be not less than the strength at 7 days.

[C] Slump or flow requirements are waived for materials intended for vertical or overhead applications.

[D] A 250-mm [10-in.] square spalled to an average depth of 3 mm [⅛ in.] for 100 % of its surface would have about 10 kg/m^2 [2.0 lb/ft^2] of scaled material.

Optional characteristics that are recommended for consideration are time of setting, flexural strength, freeze thaw, and sulfate expansion. No tests of consistency, freeze thaw, or sulfate expansion conducted on any of the products tested at the ERDC or AFRL are available for comparison with the new ASTM standard.

The following sections provide analyses of test results conducted at ERDC and other agencies to determine if current requirements set forth in ETL 08-02 (AFCESA 2008a) or ASTM C 928 (ASTM 2009) are appropriate for down selecting repair materials.

Compressive strength

As can be seen in Table 8, for ASTM C 928 (ASTM 2009), repair materials are separated based solely on their compressive strength at 3 hr, 1 day, and 7 days of cure. R1 materials are only required to gain 500 psi; R2 materials are to gain 1,000 psi; and finally, R3 materials are to gain 3,000 psi compressive strength within 3 hr as measured using ASTM C 39 (ASTM 2005) procedures. As can be seen in Figure 10, the majority of tests conducted on products gained over 2,500 psi within 2 hr of cure placing most of the rapid-setting cementitious products tested in this program in the R3 category as defined by ASTM C 928 (ASTM 2009). The current ETL requires 3,000 psi at 2 hr. Not all products tested gained this strength at 2 hr. The 2-hr requirement is critical for crater repairs during initial base recovery activities and repairs on primary runways or taxiways where expedited return to service is required. However, for permanent airfield repair activities in less critical areas, longer cure times may be possible. Obtaining 3,000 psi within the cure time available for the repair may be more applicable for permanent airfield repair activities conducted on parking aprons and secondary taxiways. For example, many materials did not achieve 3,000 psi at 2 hr, but may have achieved 3,000 psi in 3 hr of cure that would classify them as R3 materials according to the new ASTM standard. This would increase the number of repair materials adequate for repairs with a 3-hr cure time.

Comparisons of compressive strengths at one day of cure are shown in Figure 11. No 24-hr test data were available for the tests conducted at MST. Not all products that met the R3 compressive strength criteria at 3 hr gained 5,000 psi strength within one day. Data were not available for 7-day and 28-day test result comparison with the ASTM standard.

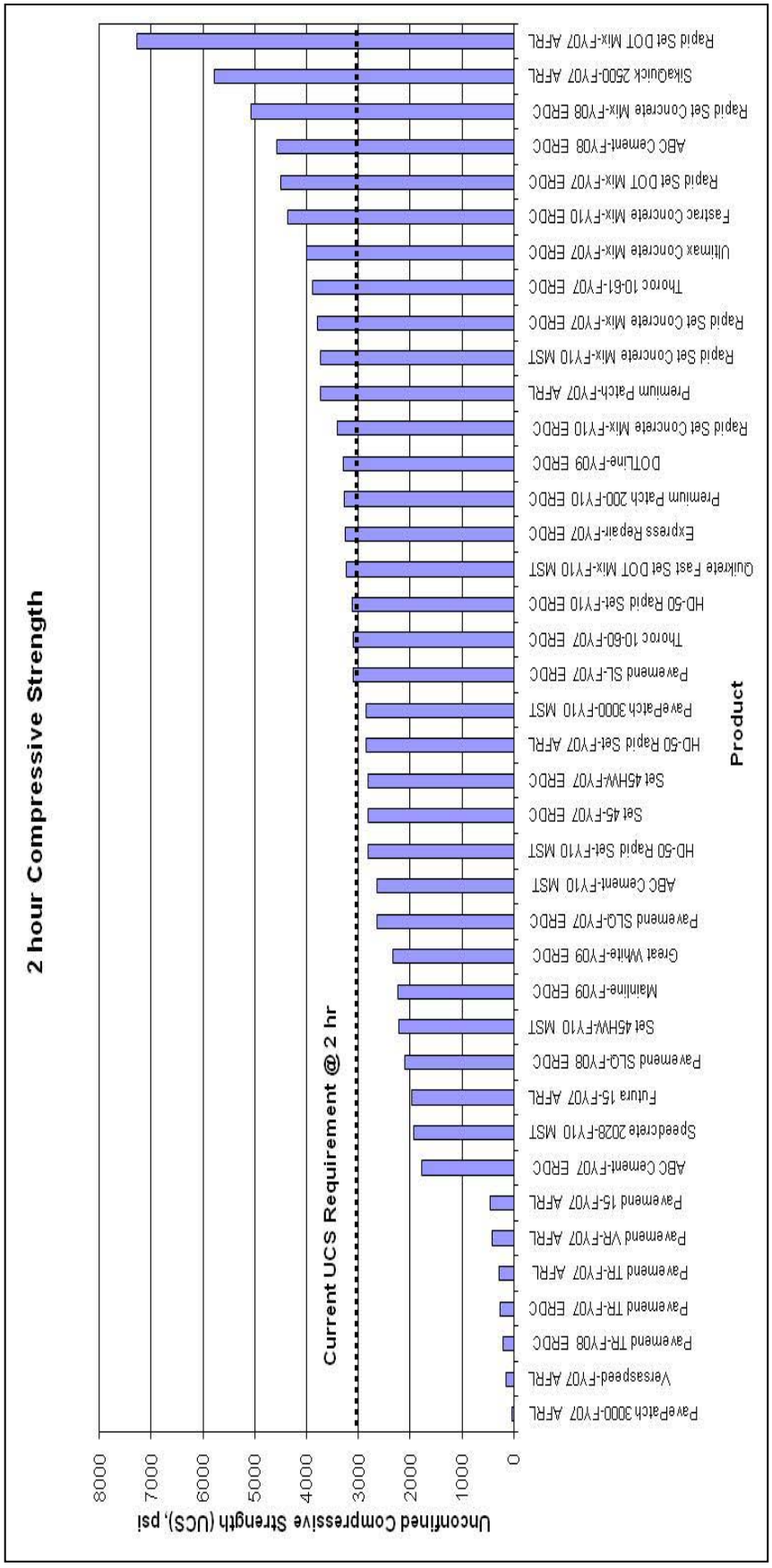

Figure 10. Product comparison of 2-hr compressive strength.

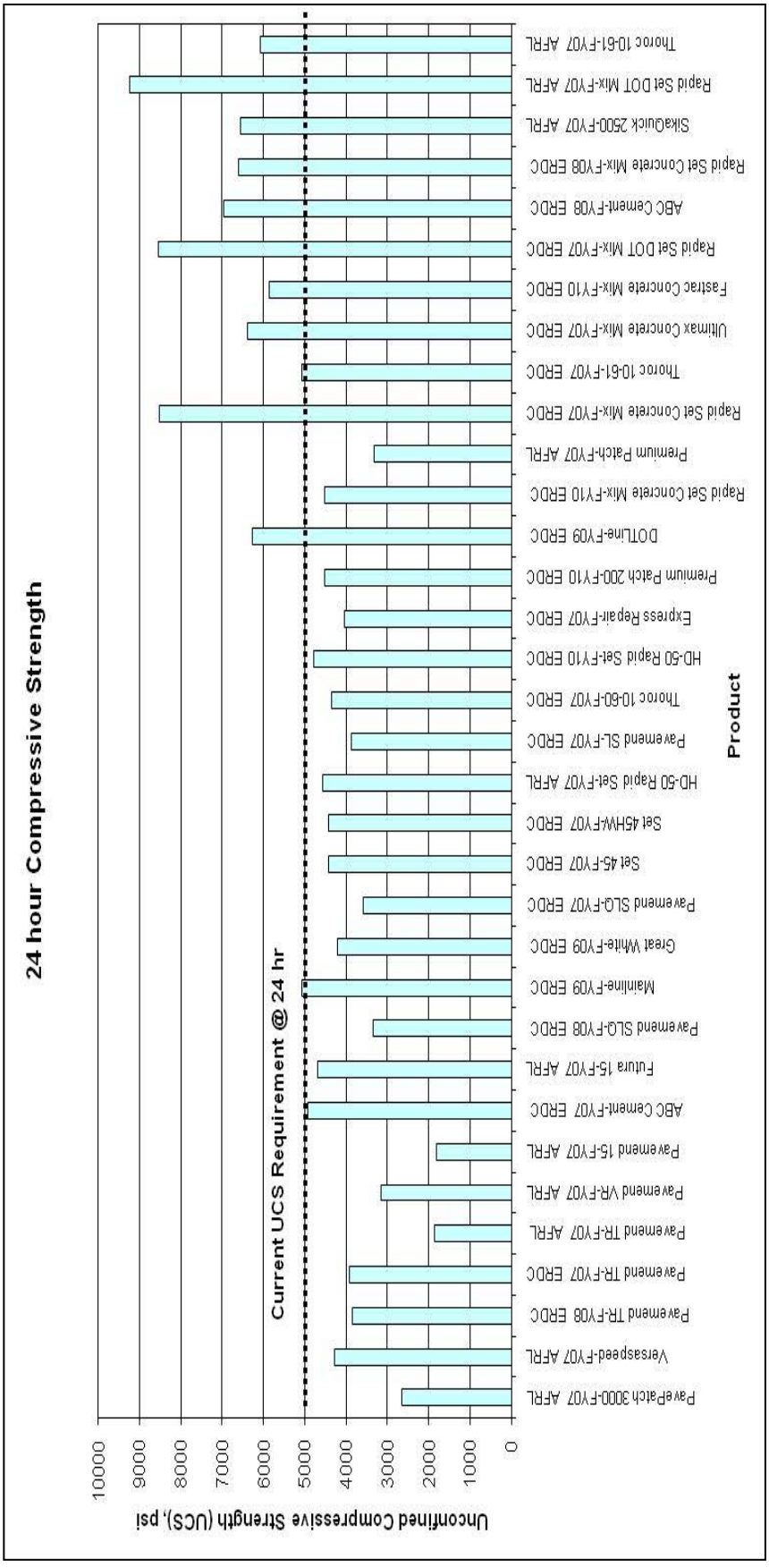

Figure 11. Product comparison of 24-hr compressive strength.

The requirement for 5,000 psi at 1 day may be most important for crater and expeditionary spall repairs that will be experiencing heavy traffic volumes within hours of repair. This requirement may also be relevant to permanent airfield repairs conducted on runway and primary taxiway surfaces. Obtaining 5,000 psi at 7 days and 28 days is suitable for permanent airfield repairs on parking aprons and secondary taxiways.

It is recommended that a minimum requirement be added to the ETL for crater and expeditionary spall repairs to obtain a minimum of 5,000 psi at 1-day cure. For permanent repairs on airfields 5,000 psi should be achieved by 7 days and maintained at 28 days. It is also recommended that the 2-hr, 3,000-psi requirement remain the minimum requirement for crater and expeditionary spall repair activities as these repairs will experience heavy traffic volumes within hours of repair. For repairs conducted on parking aprons and secondary taxiways, 3,000 psi at a specific curing time (based on repair windows for that airfield) should be specified.

Several products underwent repeat testing including Pavepatch 3000, Pavemend TR, ABC Cement, Pavemend SLQ, Set 45HW, HD-50 Rapid Set, Thoroc 10-61, and Rapid Set DOT Mix. As can be seen in these figures, variations occurred between test agencies and test years for similar products. These differences are not uncommon, as the rapid-setting cementitious materials may vary due to differences in cement chemistry and product formulation from year to year. Additionally, ranges of water content are allowed for several products, and most products that allow extension with aggregate permit “up to” a certain weight of aggregate usually pea gravel or maximum size of 0.75-in. crushed stone. Unless identical water and aggregate types/volumes are added to prepare the materials, the compressive strength of the materials will vary.

For example, Rapid Set Concrete Mix’s manufacturer mixing recommendations permit the addition of 3 to 5 qt of water per 60-lb sack of material. Figure 12 shows the difference in early compressive strength when 3.5 and 5 qt of water per 60-lb sack of material are used. If the maximum water content allowed (5 qt) is added, then the material did not gain the 3,000-psi requirement until almost 14 hr of cure. When 3.5 to 4.5 qt are added, the material achieves 3,000 psi within 2 to 3 hr. These data indicate that unless identical volumes of water were used to prepare the laboratory samples from each laboratory, the resulting compressive strengths would vary.

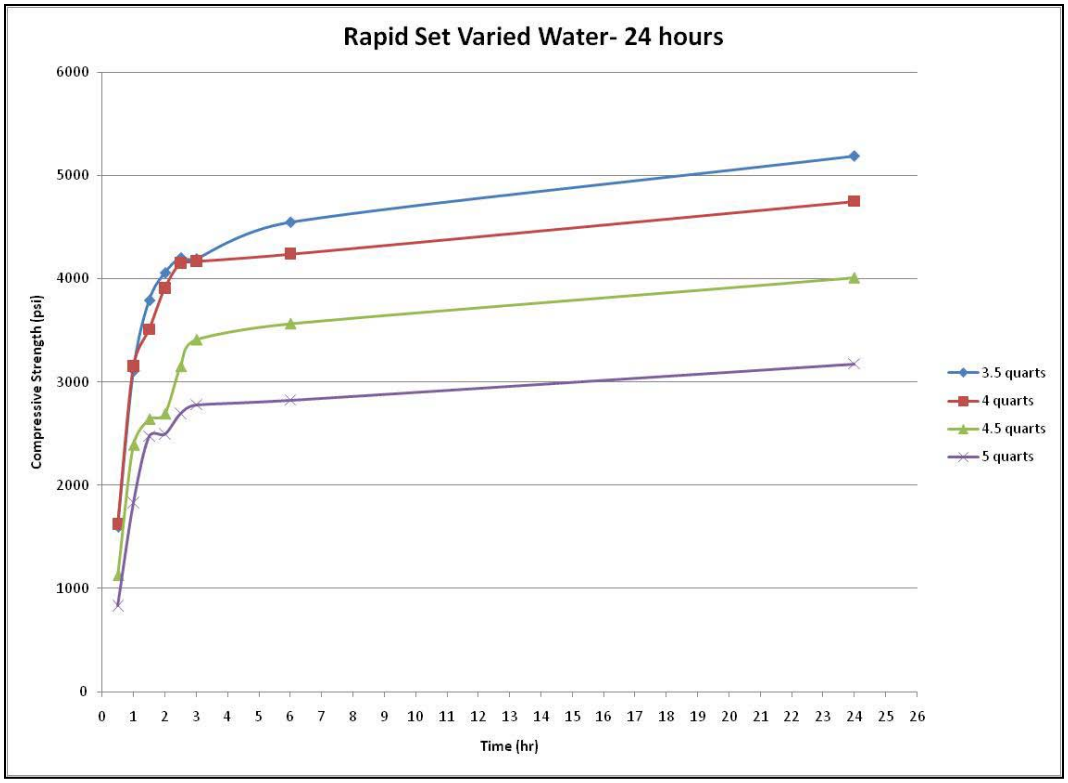

Figure 12. Comparison of compressive strengths for Rapid Set Concrete Mix for varied water contents.

Due to limited record keeping, the liquid and aggregate amounts added for laboratory batching were not always recorded on the data sheets provided in the appendices. It is recommended that this information should be required to be placed in each fact sheet under “mixing instructions” for future tests conducted for this program.

If water and aggregate volumes were controlled between materials tested, material reformulation would be better indicated by drastic differences between testing over time. Because reformulation of materials or changes in component chemistry are common for these product types (Priddy et al. 2007), retest of materials following identical laboratory procedures are recommended. As mentioned in “Background”(Chapter 2), NTEP retests materials every 5 years to check for reformulation changes to material properties. Unless the material vendor discloses a reformulation of material and new mixing instructions, identical mixing procedures to previous tests should be followed. It is recommended that materials be retested every 5 years.

Flexural strength

Flexural strength tests were conducted on numerous products as presented previously. ASTM C 928 (ASTM 2009) does not provide minimum performance requirements for this test (ASTM C 78) (ASTM 1994; ASTM 2008b). The current ETL 08-02 (AFCESA 2008a) requires that the materials develop a minimum flexural strength of 350 psi within 2 hr and recommends testing again at 1 day, but the ETL does not require a minimum value for the 1-day test. Flexural strength is commonly required for acceptance of materials used in PCC airfield construction; however, many agencies now specify compressive strength in lieu of flexural strength. PCC is usually assumed to be about 10 to 12 percent as strong in tension as it is in compression. Tensile strength is the basis for its ability to resist bending, or its flexural strength. Resistance to bending without cracking may be more important for full-slab replacements than for smaller repairs such as spalls, small patches, and large patches that may not experience large tensile forces.

Figure 13 presents the 2-hr flexural strength results for the products tested. The current requirement of 350 psi is almost met or exceeded by the majority of products tested. A 350-psi minimum strength at 2 hr is most likely adequate for repair material selection for full-slab replacement for permanent airfield repairs and for large crater repairs involving multi-slab replacement. By 7 days and 28 days, the repair material should obtain 600 psi assuming the minimum compressive strength at 28 days is 5,000 psi, 12 percent of this is 600 psi. Materials not meeting minimum requirements are not recommended for full-slab replacement.

It is recommended that the ETL be modified so that the minimum requirement at 2 hr is 350 psi with a 600-psi minimum at 7 days and 28 days to be consistent with the recommendation for the compressive strength minimum requirements for full-slab replacement activities only on primary runways and taxiways. Longer cure times (i.e., 350 psi at 3 hr) may be specified for parking aprons and secondary taxiways; however, the 600-psi requirement at 7 and 28 days should remain.

Bond strength

Bond strength tests were conducted on numerous products. ASTM C 928 (ASTM 2009) provides minimum performance requirements for this test of 1,000 psi at 1 day and 1,500 psi at 7 days for cementitious, rapid-setting

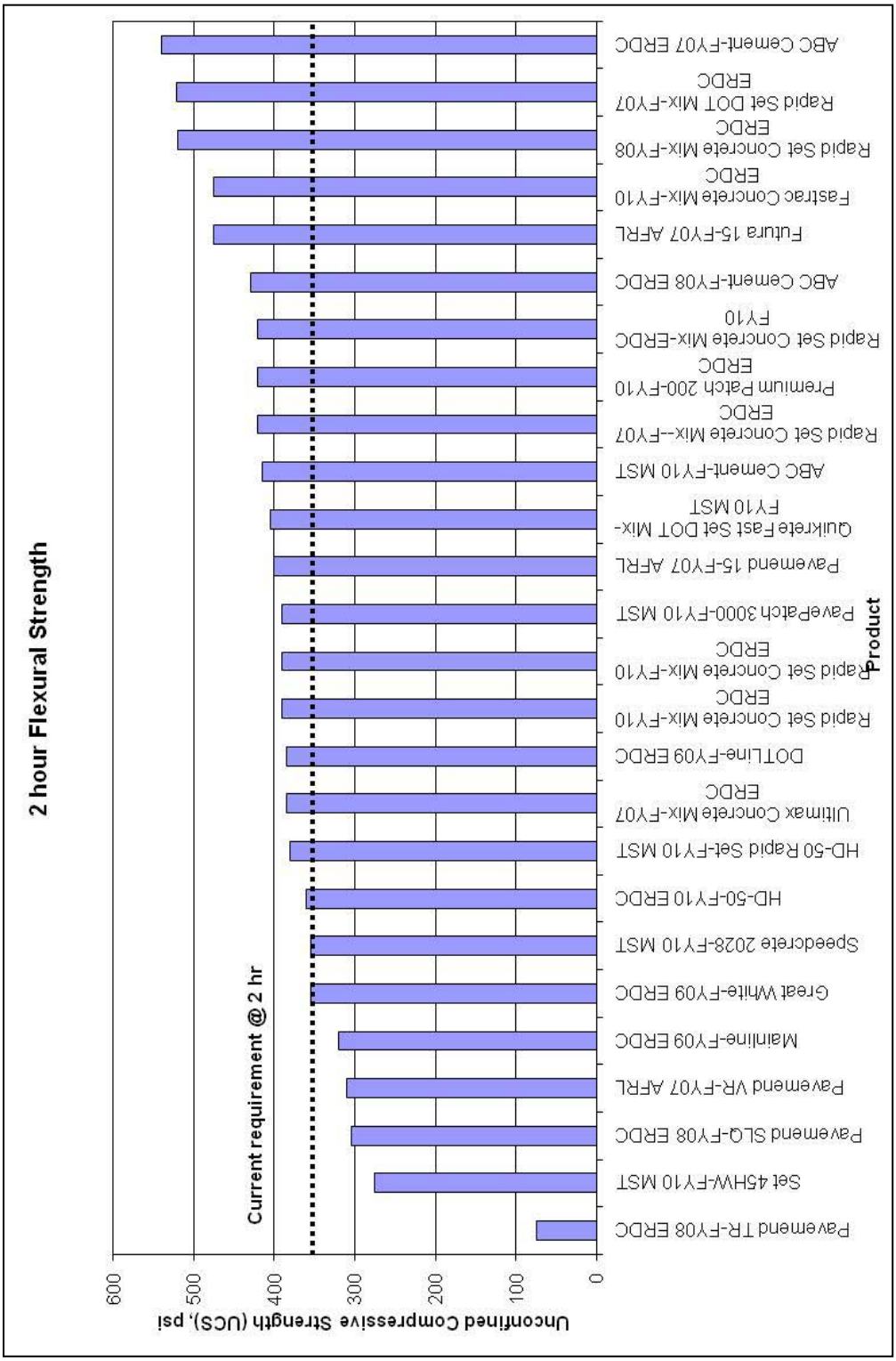

Figure 13. Product comparison of 2-hr flexural strength.

repair material bonded to OPC. The current ETL 08-02 (AFCESA 2008a) requires testing for both rapid-setting material bonded to OPC and rapid-setting material bonded to rapid-setting material. A minimum of 850 psi is required at 1 day for cementitious, rapid-setting repair material bonded to OPC and 1,000 psi for cementitious, rapid-setting repair material bonded to cementitious, rapid-setting repair material.

Figure 14 presents a comparison of the bond strength of repair materials bonded to OPC after 1 day of cure. Figure 15 presents the bond strength of repair materials bonded to themselves after 1 day of cure. Bond testing was always conducted, but most materials investigated are represented in this figure. The current requirement of 850 psi is almost met or exceeded by the majority of products tested. The only bond problem evidenced in field testing of the numerous products was with Express Repair in 2007 which exhibited a bond strength of 720 psi. This was below the minimum requirement of 850 psi. The ETL requirement of 850 psi could be modified to match the ASTM C 928's 1,000-psi requirement (ASTM 2009). Fewer tests have been accomplished with the rapid-setting material to rapid-setting material. The available data are presented in Figure 14. The only material not meeting a minimum requirement of 1,000 psi was Express Repair.

Bond strength is important for expeditionary spall repairs; however, materials that performed well for temporary spall repairs including Futura 15, Pavemend TR, and Pavemend VR were below the minimum value for bond strength of repair material bonded to OPC. Changing the bond strength between a repair material and itself in the ETL to 1,000 psi is recommended. Further, long-term investigation is also recommended to determine if repairs made with materials recommended for expeditionary spall repairs perform adequately long term despite reduced bond strength results.

Modulus of elasticity

Figure 16 presents the modulus of elasticity as measured for products following a 2-hr cure. Figure 17 shows the range in values for the materials tested after a 3-day cure. As can be seen by the figure, some materials exceeded the current ETL requirements of being greater than 2×10^6 psi after 2 hr and greater than 4×10^6 psi after 3 days of cure. Mindess et al. (2003) provided a range of acceptable modulus of elasticity values for

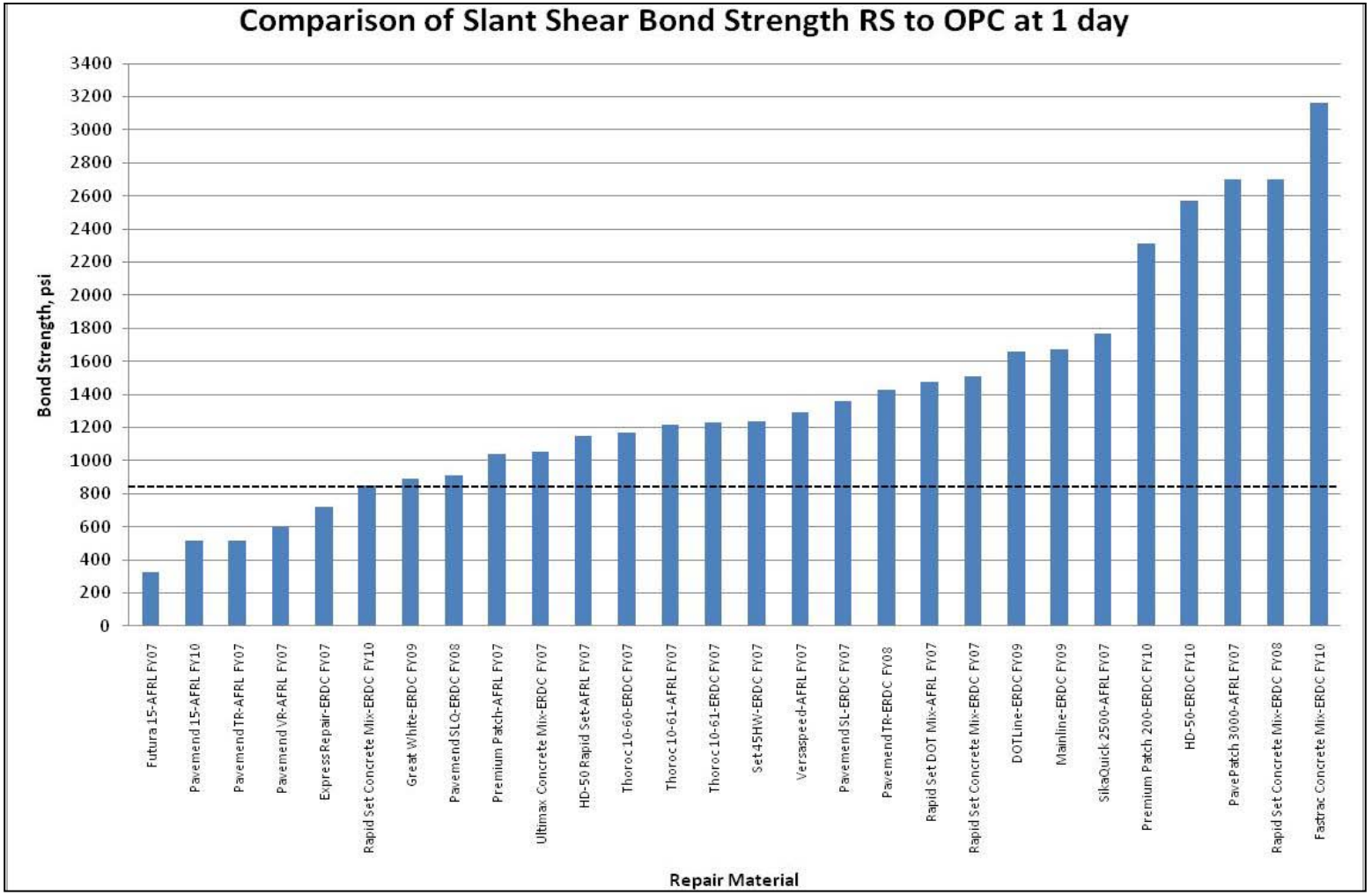

Figure 14. Comparison of product bond strength to OPC at 1-day cure.

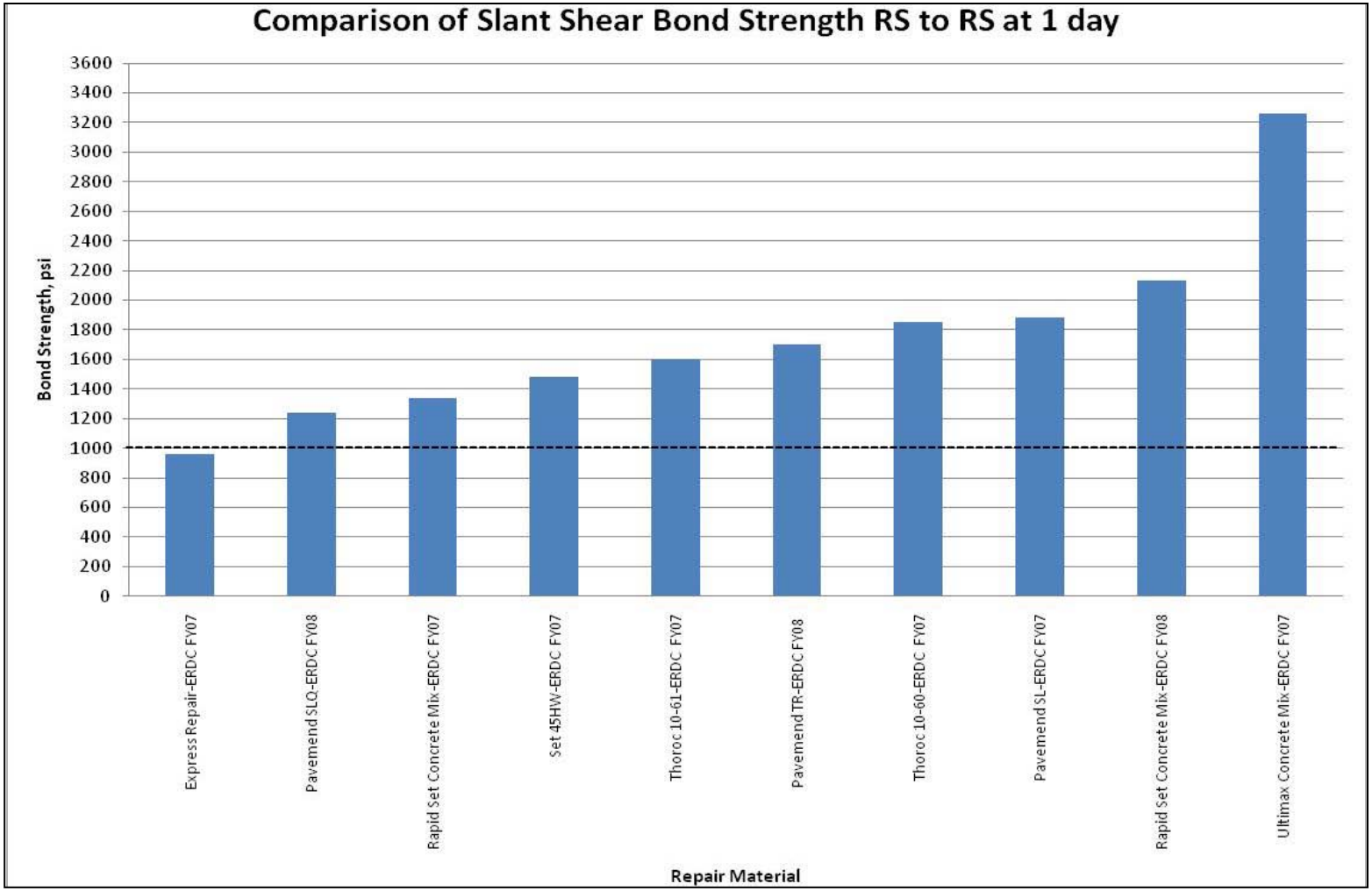

Figure 15. Comparison of product bond strength to self at 1-day cure.

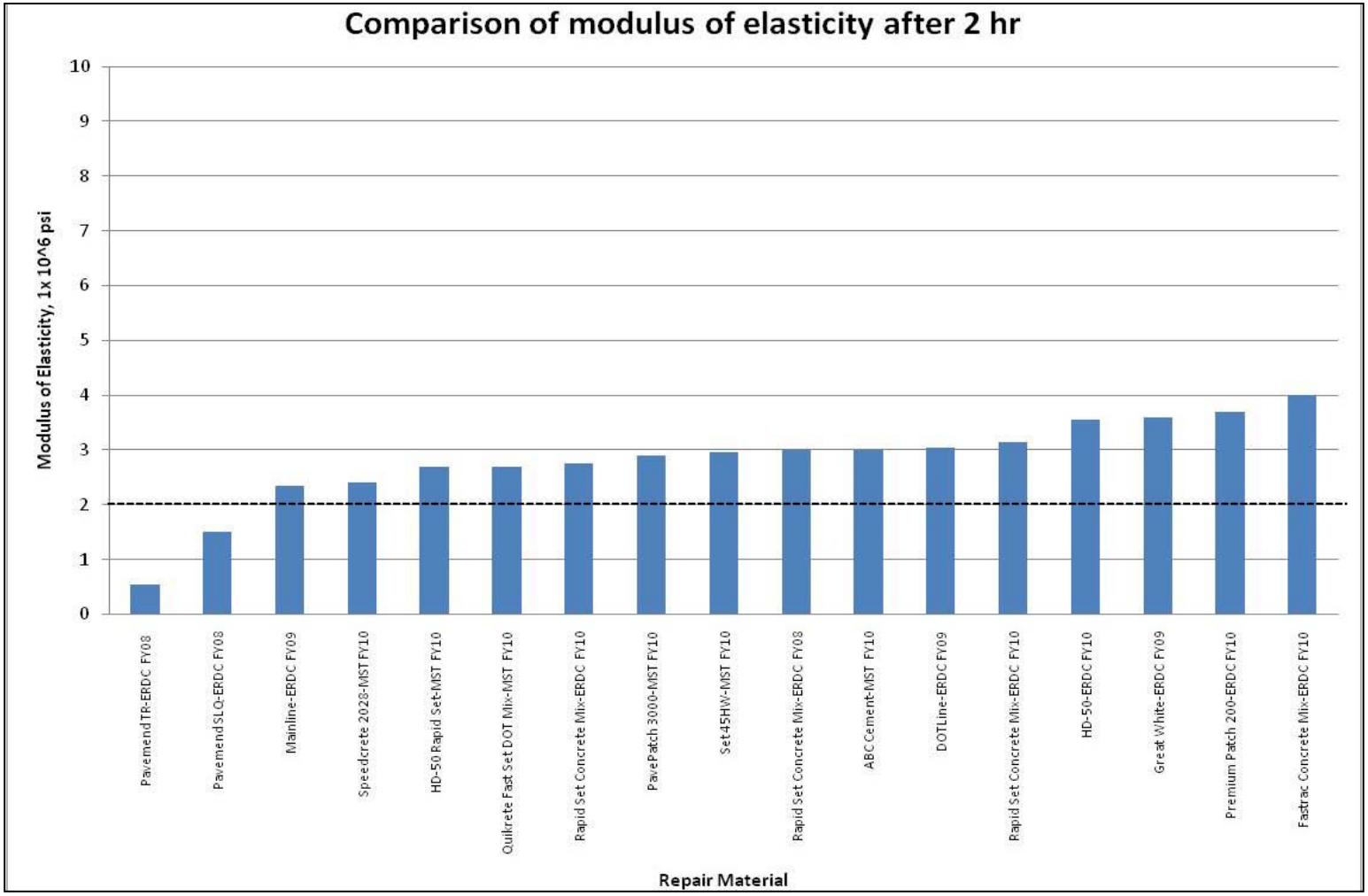

Figure 16. Comparison of product modulus of elasticity after 2-hr cure.

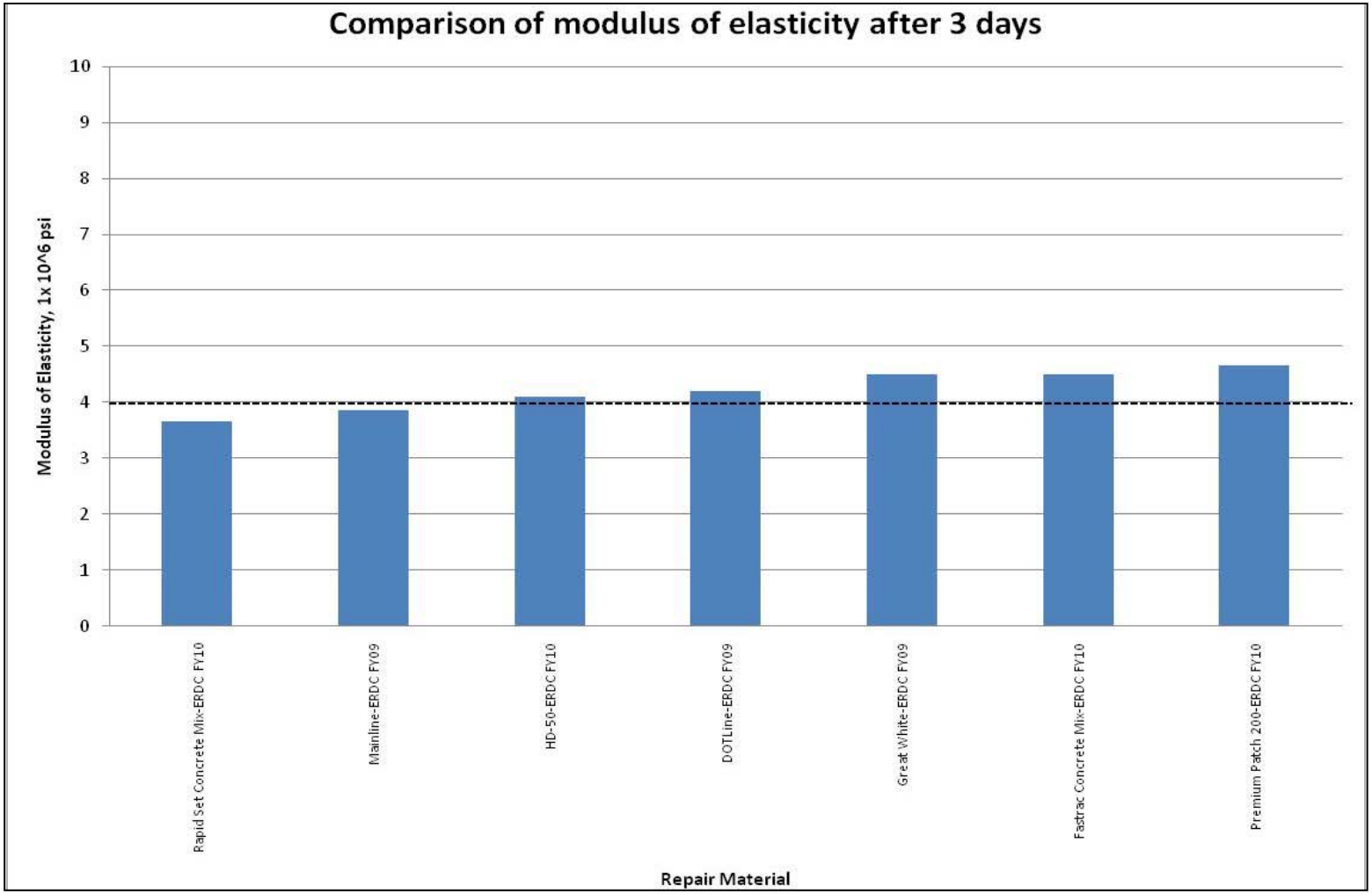

Figure 17. Comparison of product modulus of elasticity after 3-day cure.

normal PCC between 2×10^6 and 6×10^6 psi measured at 28 days. The requirement of 4×10^6 psi at 3 days had been set as the average between the normal PCC range, and the requirement of being less than 2×10^6 psi after 2 hr was set based on the lower bound of normal PCC ranges. By setting an upper limit for the repair materials to 6×10^6 psi, testing at 2 hr and 28 days may be a more reasonable requirement for the repair materials. Because the materials gain strength so quickly, it is important for the materials to have reached at least 2×10^6 psi within 2 hr but not to exceed 6×10^6 psi in either the 2-hr or the 28-day test. It is recommended that the ETL be modified to reflect that range in the modulus for both tests.

Coefficient of linear thermal expansion

In 2008, Priddy et al. reported significant volume changes on repairs performed using Pavemend SLQ. Because shrinkage and expansion problems occurred, it was recommended that repair materials have a coefficient of thermal expansion similar to normal PCC pavements. Excessive expansion will result in the loss of bond to the parent material. Additionally, for large repairs, excessive expansion can result in the deterioration of the surrounding pavements. The coefficient of linear thermal expansion upper limit is typically 8 to 12×10^{-6} in./in./°F for normal concrete. ASTM C 928 (ASTM 2009) does not set minimum or maximum values for this property as measured by ASTM C 531. In ETL 08-02 (AFCESA 2008a), the current requirement is for the repair material to have a value of $\leq 7 \times 10^{-6}$ in./in./°F beginning at a test age of 3 days. As shown in Figure 18, not all materials tested have been tested for their expansive properties. As can be seen by this figure, all but one of the materials tested were within the current requirement set by the ETL.

A more recent test of the material shows that this property (as with other properties) varies with year and agency. This is most likely due to water contents and aggregates within the mixes that vary from one test year to the next. However, if one considers the normal concrete acceptable maximum range of 8 to 12×10^{-6} in./in./°F, all the repair materials test results presented in the figure are within the acceptable range. This indicates that the testing did not identify any material that exhibited thermal expansion characteristics that exceed those of normal concrete (which should not result in damage to surrounding pavements if the materials are used for long-term repair and replacement).

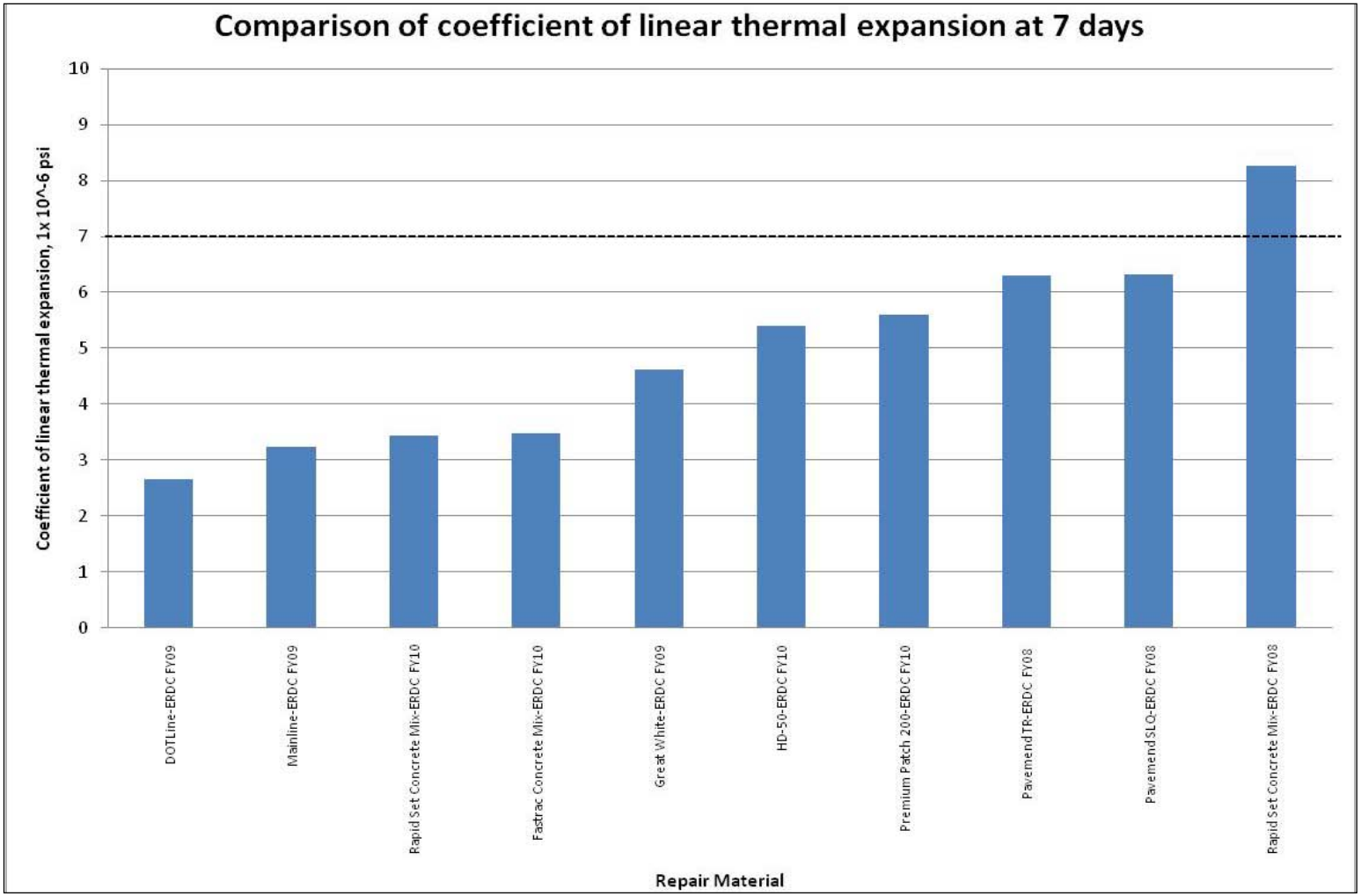

Figure 18. Comparison of product coefficient of linear thermal expansion after 7-day cure.

It is recommended that the requirement in the ETL be changed to an upper limit of 12×10^{-6} in./in./°F with a test age of 7 days, not 3 days as currently shown, to agree with ASTM requirements for this test procedure.

Volumetric expansion/shrinkage

Because shrinkage and expansion problems have occurred with repair materials in the past (Priddy et al. 2008), it was recommended that repair materials be subjected to additional expansion and shrinkage tests including maximum length change requirements. Excessive expansion or shrinkage will result in the loss of bond to the parent material. Additionally, for large repairs, excessive expansion can result in the deterioration of the surrounding pavements.

ETL 08-02 (AFCESA 2008a) requires that the maximum allowable increase in length not exceed 0.03 percent when cured in water and the maximum allowable decrease not exceed 0.04 percent after 28 days curing in air when tested in accordance with ASTM C 157 (ASTM 2008c). These values were set forth in the ETL based on typically accepted values for normal PCC of 0.03 to 0.05 percent (Priddy et al. 2008).

ASTM C 928 (ASTM 2009) provides the maximum allowable increase in length change as 0.15 percent after 28 days in water and the maximum allowable decrease as -0.15 percent after 28 days in air. This range for maximum allowable expansion and contraction is so broad that most materials fall between the limits. These values were determined based on the investigation of a single repair material by seven different laboratories as detailed in ASTM C 928.

As mentioned previously, in 2008, Priddy et al. identified a problem of significant volume changes with Pavemend SLQ. Laboratory testing of this material, from the same batch of material used in the field tests where the problem occurred, measured a maximum length change (expansion) of a specimen cured in a moist cabinet held at 73°F on the order of 0.15 percent. No shrinkage was recorded. Based on both the ETL data, this material would not have been acceptable due to its expansive properties. According to ASTM C 928, the material would have been borderline acceptable.

Results of investigations into additional repair materials in 2009 and 2010 are presented in Figure 19. Data presented in the figure only include materials tested after expansion problems were identified in the repair materials. Most of the remaining repair materials met the requirements of the

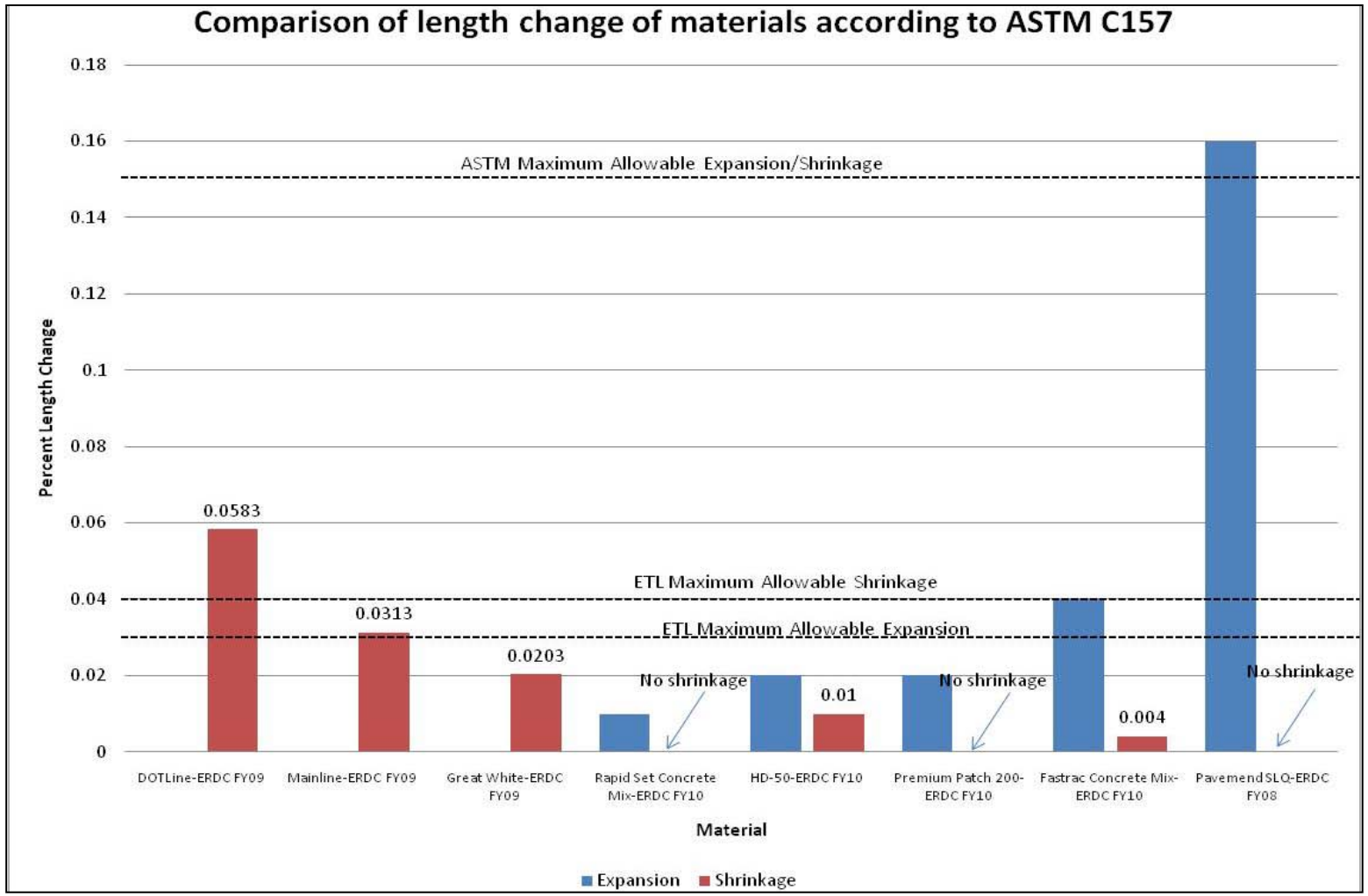

Figure 19. Comparison of repair material expansion and shrinkage percentages (length change).

current ETL for shrinkage and expansion. Exceptions were DOTLine and Mainline that failed due to excessive shrinkage and Fastrac Concrete Mix that failed due to excessive expansion.

Long-term investigation into expansion and shrinkage is recommended to determine if the current ETL requirements should be changed to match the ASTM requirements. However, the initial data indicate that the new ASTM standard is too permissive. DOTLine did not perform well in field tests, and Fastrac has not been field tested. Additionally, only few repairs have been left in place for assessment of long-term repair performance (including Pavemend SLQ, Rapid Set Concrete Mix, Set 45 HW, Thoroc 10-60, and Thoroc 10-61). Until further investigations are completed, it is recommended that the ETL requirements remain the same for all repair types.

Shrinkage potential

ASTM C 928 (ASTM 2009) does not provide a requirement for conducting tests of shrinkage potential outside of ASTM C 157 (ASTM 2008c) testing. The restrained ring device is specified as an additional test of shrinkage in ETL 08-02 (AFCESA 2008a). The ETL requires that less than 40 microstrain be measured after 14 days and that no cracking occur within 28 days of casting. Data were collected following ASTM C 1581 (ASTM 2004a) during FY08 through FY10 (Table 9). No data were available for products tested prior to FY08. Additionally, no ring shrinkage test results were available for products tested by MST. The ring shrinkage data agreed with the length change data presented previously that Mainline and DOTLine experienced more shrinkage than the other products tested. The remaining products tested met the requirements set forth in the ETL.

No changes to the ETL are recommended for this test, and the requirement is recommended for application to all repair types.

Freeze thaw

Currently, no freeze-thaw requirements are set forth in ETL 08-02 (AFCESA 2008a). When the ETL was first drafted, consideration was given to a requirement that the repair materials should have ≤50 percent loss in relative dynamic modulus of elasticity after 50 freeze-thaw cycles with testing to be done after 3 days of cure following ASTM C 666 (ASTM 2008d). ASTM C 928 also recommends using ASTM C 666 (ASTM 2008d) test procedure but requires only 25 cycles of freezing and thawing.

Table 9. Ring shrinkage test results FY08-FY10.

Product	Test Year	Test Agency	Pass/Fail
Pavemend TR-ERDC FY08	FY08	ERDC	Pass
Pavemend SLQ-ERDC FY08	FY08	ERDC	Pass
Rapid Set Concrete Mix-ERDC FY08	FY08	ERDC	Pass
ABC Cement -ERDC FY08	FY08	ERDC	Pass
Mainline-ERDC FY09	FY09	ERDC	Fail
DOTLine-ERDC FY09	FY09	ERDC	Fail
Great White-ERDC FY09	FY09	ERDC	Pass
Rapid Set Concrete Mix-ERDC FY10	FY10	ERDC	Pass
HD-50-ERDC FY10	FY10	ERDC	Pass
Premium Patch 200-ERDC FY10	FY10	ERDC	Pass
Fastrac Concrete Mix-ERDC FY10	FY10	ERDC	Pass

ASTM C 928 (ASTM 2009) also recommends recording the scaling resistance to deicing chemicals after 25 cycles in accordance to ASTM C 672/C 672M (ASTM 2003) with the exception of omitting data collection at 5 cycles. For this test, the maximum visual rating is 2.5 for concrete and maximum scaled material is 1 lb/ft^2 for mortar.

It is recommended that freeze-thaw and scaling resistance be investigated for the top performing repair materials, as identified through the 5 years of investigation. The testing requirements described in ASTM C 928 tests should be conducted as a minimum to identify requirements for ETL 08-02 (AFCESA 2008a). Once requirements are determined, application of the requirement should be restricted to airfields that undergo freeze-thaw cycling.

Set time

The amount of working time available for cementitious, rapid-setting repair material placement is important to those performing repairs. For large repairs, the set time needs to be long enough so that the entire repair may be placed before portions begin to set in order to reduce the need for a number of thin horizontal lifts or the need for setting formwork for placing smaller full-depth sections. As mentioned previously, many materials require mixing in buckets or in small volumes. These materials generally have shorter initial and final set times, some as short as 5 min or less. Set times this short would require mixing numerous small batches of material

or simultaneous mixing of multiple batches for a large repair. Even so, thin horizontal lifts may occur.

Time of set for initial and final setting of materials, as measured in accordance with ASTM C 191 (ASTM 2004b), has been collected for materials over the last several years and is presented in Figure 20. Set time data collected in 2007 by ERDC was not included in this figure because the values were not measured according to ASTM C 191 (ASTM 2004b). The data presented in this figure show the majority of repair products achieve initial set within 35 min and final set within 45 min.

Because larger volumes of repair materials are required for crater repairs, large patches, and full-slab replacements, an initial set greater than 15 min and a final set of greater than 25 to 35 min are recommended. Shorter initial set times for spall repairs and small patches may be allowed as less working time is required for these smaller volume repairs. Obviously extended set times would negate the "rapid-setting" nature of these materials. Thus, a maximum set time of 45 min should be maintained to ensure that the chemical reactions are progressing and provide the material with enough active cure time to achieve the required strength values.

Slump

ASTM C 928 (ASTM 2009) recommends a minimum slump of 3 in. for cementitious, rapid-setting materials. No slump requirements are currently set forth in ETL 08-02 (AFCESA 2008a); however a recommendation of 3 in. is a reasonable requirement for ease-of-placement of materials. A higher slump may be required for large crater repair and full-slab replacement to reduce labor on workers conducting the repairs. Specifying a higher slump increases the risk that segregation of aggregate may occur. No slump data exist for materials tested at ERDC, but it is recommended that future work include this test.

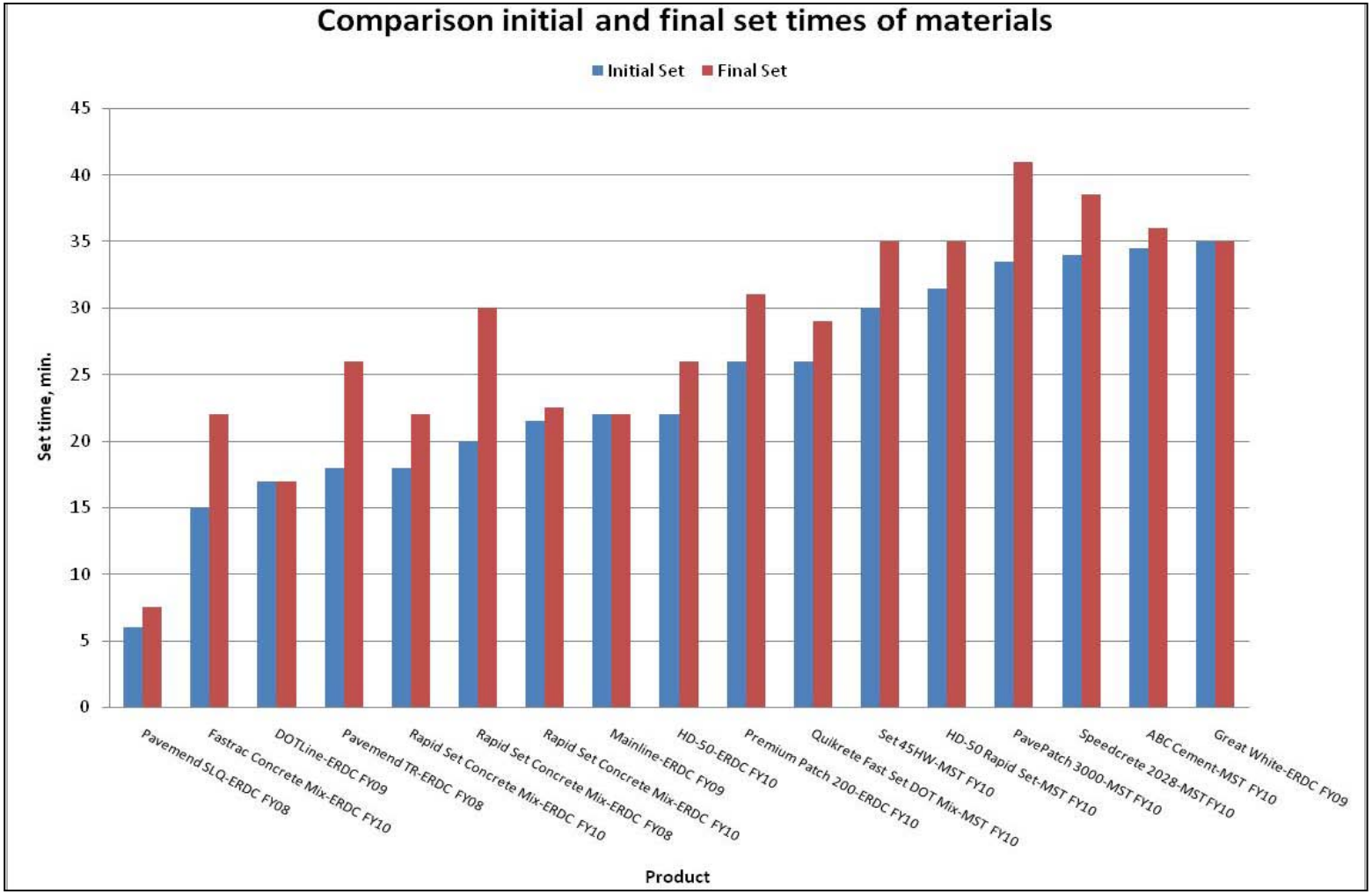

Figure 20. Comparison of set times for materials.

5 Conclusions and Recommendations

This research identified the key characteristics of successful rapid-setting repair materials, tested a number of repair materials currently used or marketed to the DOD, and compiled the information for use in a repair material selection process. Additionally, tests were performed on a number of field repairs, and the field placement and performance under simulated aircraft traffic was observed in an effort to correlate laboratory data to field performance results. Even though several tests were conducted in the laboratory to characterize selected material properties, no single property was deemed a sole indicator of performance.

Repair material recommendations

A review of laboratory and field tests conducted at ERDC and other agencies from 2006 to present was completed in this investigation. Table 10 provides a repair material selection table to aid repair units or airfield repair managers in selecting materials for particular applications or missions. Fact sheets detailing each product are provided in the appendices.

Performance test parameters

Conclusions and recommendations for numerous laboratory test parameters are presented in this section. Table 11 provides a summary for the test requirements recommendations presented in the following sections.

Compressive strength

Modifications to the ETL for compressive strength are recommended. The following conclusions and recommendations are provided:

- The 2-hr 3,000-psi requirement is important to temporary repairs including crater and expeditionary spall repair activities as these repairs will experience heavy traffic volumes within hours of repair; however, for permanent airfield repair activities, longer cure times may be acceptable.

Table 10. Repair material/repair type selection table.

Repair Material	Temporary Repairs			Permanent Airfield Repairs							
	Crater Repairs			Primary Runways and Taxiways				Secondary Runways, Secondary Taxiways, and Parking Aprons			
	Small	Large	Expeditionary Spall Repairs	Spall	Small Patch	Large Patch	Full Slab	Spall	Small Patch	Large Patch	Full Slab
ABC Cement	X	X		X	X	X	X	X	X	X	X
Great White							X				X
HD-50 Rapid Set			X	X	X			X	X		
Pavemend 15			X								
Pavemend SLQ			X	X	X			X	X		
Pavemend TR[a]								X	X	X	
Pavepatch 3000			X					X	X		
Premium Patch 200			X	X	X			X	X		
Quikcrete Fast Set DOT Mix			X					X	X		
Rapid Set Concrete Mix	X	X	X	X	X	X	X	X	X	X	X
Rapid Set DOT Mix			X								
Set 45 HW	X		X	X	X	X		X	X	X	
Set 45	X		X	X	X	X		X	X	X	
SikaQuick 2500			X	X	X			X	X		
Thoroc 10-60	X	X	X	X	X	X	X	X	X	X	X
Thoroc 10-61	X	X	X	X	X	X	X	X	X	X	X
Ultimax Concrete Mix	X	X	X	X	X	X	X	X	X	X	X
Versaspeed			X								

[a] Research indicates that this material requires 4 hr of curing prior to opening to traffic.

Table 11. Test result requirements for cementitious repair materials.

Property	ASTM	Temporary Repairs		Permanent Airfield Repairs	
		Crater Repair	Expeditionary Spall Repair	Primary Runways and Taxiways	Secondary Runways, Secondary Taxiways, and Parking Aprons
Compressive strength	C 39	≥ 3,000 psi at age of 2 hr[a] ≥ 5,000 psi at age of 1 day	No laboratory requirement at this time. Requires field testing prior to approval.	≥ 3,000 psi at 2 hr or at age of opening ≥ 5,000 psi at age of 1 day	≥ 3,000 psi at specified age of opening ≥ 5,000 psi at age of 7 days and 28 days
Flexural strength	C 78	Not required	Not required	≥ 350 psi at age of 2 hr ≥ 600 psi at age of 7 days and 28 days Full-slab replacement only	≥ 350 psi at specified age of opening ≥ 600 psi at age of 7 days and 28 days Full-slab replacement only
Bond strength	C 882	≥ 1,000 psi (repair bonding to OPC mortar) ≥ 1,000 psi (repair material bonding to repair material) Test at age of 1 day.	≥1,000 psi (repair bonding to OPC mortar) ≥1,000 psi (repair material bonding to repair material) Test at age of 1 day.	≥ 1,000 psi (repair bonding to OPC mortar) ≥ 1,000 psi (repair material bonding to repair material) Test at age of 1 day.	≥1,000 psi (repair bonding to OPC mortar) ≥1,000 psi (repair material bonding to repair material) Test at age of 1 day.
Modulus of elasticity	C 469	2×10^6 to 6×10^6 psi Test at age 2 hr and 28 days.	2×10^6 to 6×10^6 psi Test at age 2 hr and 28 days.	2×10^6 to 6×10^6 psi Test at age 2 hr and 28 days.	2×10^6 to 6×10^6 psi Test at age 2 hr and 28 days.
Volumetric expansion	C 531	≤ 12×10^{-6} in./in./°F Test begins at age of 7 days.	≤12×10^{-6} in./in./°F Test begins at age of 7 days.	≤ 12×10^{-6} in./in./°F Test begins at age of 7 days.	≤ 12×10^{-6} in./in./°F Test begins at age of 7 days.
	C 157	<+0.03% expansion or <-0.04% shrinkage @ 28 days	<+0.03% expansion or <-0.04% shrinkage @ 28 days	<+0.03% expansion or <-0.04% shrinkage @ 28 days	<+0.03% expansion or <-0.04% shrinkage @ 28 days
Shrinkage potential	C 1581	≤ 40 microstrain at 14 days and no cracking at 28 days Test begins at time of casting.	≤40 microstrain at 14 days and no cracking at 28 days Test begins at time of casting.	≤ 40 microstrain at 14 days and no cracking at 28 days Test begins at time of casting.	≤ 40 microstrain at 14 days and no cracking at 28 days Test begins at time of casting.

Property	ASTM	Temporary Repairs		Permanent Airfield Repairs	
		Crater Repair	Expeditionary Spall Repair	Primary Runways and Taxiways	Secondary Runways, Secondary Taxiways, and Parking Aprons
Freeze-thaw resistance	C 666	Not required	Not required	No requirement at this time	No requirement at this time
Time of setting[b]	C 191	15 min initial set 25 to 35 min final set	Not required	15 min initial set 25 to 35 min final set	15 min initial set 25 to 35 min final set
slump	C143	Record slump	Record slump	Record slump	Record slump

[1] Field verification of material performance can be used in lieu of achievement of the test requirements. Consult https://transportation.wes.army.mil/triservice/pavement_repair.aspx. for a list of approved products.

[2] Recommended initial and final set times of 15 min and 25 min are provided. For small repairs or spall repairs, shorter initial and final set times may be acceptable.

- Obtaining 3,000 psi as a minimum opening requirement within the cure time available for the repair is recommended for permanent airfield repair activities conducted on parking aprons and secondary taxiways. 3,000 psi for specific curing times may be specified for runway repairs and primary taxiway repairs.
- The 24-hr, 5,000-psi requirement is most important to temporary repair activities as these repairs will experience heavy traffic volumes within a few hours of repair. This requirement may also be more relevant to permanent airfield repairs conducted on runway and primary taxiway surfaces.
- Obtaining 5,000 psi within 7 days and 28 days as a requirement is more relevant for permanent airfield repairs on parking aprons, secondary taxiways.

Flexural strength

Modifications to the ETL for flexural strength are recommended. The following conclusions and recommendations are provided:

- Flexural strength properties are commonly required for placement of conventional PCC and more relevant to repair materials to be used for full-slab replacement. This property is less relevant for large crater repairs requiring full or multi-slab replacements as these temporary repairs are not expected to be in place for long durations.
- A minimum flexural strength of 350 psi within 2 hr of cure and 600 psi after 7 and 28 days of cure should be required for permanent airfield repairs for full-slab repairs conducted on primary runways or primary taxiways. Longer cure times (i.e., 350 psi at 3 hr) may be specified for parking aprons and secondary taxiways; however, the 600 psi requirement at 7 and 28 days should remain.

Bond strength

Modifications to the ETL for bond are recommended. The following conclusions and recommendations are provided:

- The minimum bond strength requirement for spall repairs between a rapid-setting repair material and OPC or the repair material itself should be increased to 1,000 psi should be applied to all repair types.
- Further investigation into the bond performance of the repairs long-term is also recommended to determine if materials recommended for

expeditionary spall repairs with low bond strength perform adequately in long-term repairs.

Modulus of elasticity

A modification to the ETL for modulus of elasticity is recommended. The following conclusions and recommendations are provided:

- A lower limit of 2×10^6 psi within 2 hr and not exceeding 6×10^6 psi in 28 days is recommended.
- This recommendation is made for all repair types.

Coefficient of linear thermal expansion

A modification to the ETL for coefficient of linear thermal expansion is recommended. The following recommendation is provided:

- It is recommended that the ETL requirement be changed to an upper limit of 12×10^{-6} in./in./°F with a test age of 7 days, not 3 days as shown in the ETL, to agree with ASTM requirements for this test procedure.
- This recommendation is made for all repair types.

Volumetric expansion/contraction

Modification to the ETL for volumetric expansion/contraction is not recommended. The following conclusions and recommendations are provided:

- Long-term testing into expansion and shrinkage is recommended to determine if the current ETL requirements require changing to the ASTM requirements. The ASTM requirements appear overly permissive based upon the current data.
- It is recommended that the ETL requirements remain the same for all pavement repairs until further investigations can be completed.

Shrinkage potential

No changes to the ETL are recommended for this test.

- The requirement should remain ≤40 microstrain at 14 days and no cracking at 28 days. Test begins at time of casting.

- It is recommended that the ETL requirements be applied for all pavement repair types.

Freeze-thaw

Modification to the ETL for freeze thaw is not recommended. The following conclusions and recommendations are provided:

- It is recommended that freeze-thaw testing and scaling resistance be investigated for top performing repair materials identified through the 5 years of investigation.
- The proposed ETL tests and ASTM C 928 (ASTM 2009) tests should be conducted as a minimum to determine minimum requirements for revising ETL 08-02 (AFCESA 2008a). Once determined, this requirement should be restricted to pavements that undergo freeze-thaw cycling.

Time of set

Modification to the ETL for time of set is recommended. The following conclusions and recommendations are provided:

- Because of the large volumes of material required for crater repairs, large patches, and full-slab replacements, an initial set of greater than 15 min and a minimum final set time of 25 to 35 min are recommended based on this data for conducting crater repairs and large patches and full-slab replacements.
- Shorter initial set times for spall repairs and small patches may be allowed as less working time is required for these smaller volume repairs. Currently, no recommendation for expeditionary spall repairs exists; however, the same requirements for other repairs may be applied.

Slump

Modification to the ETL to require reporting of slump is recommended. The following conclusions and recommendations are provided:

- No slump requirements are currently set for ETL 08-02 (AFCESA 2008a); however, a recommendation of a minimum slump of 3 in. may be a reasonable requirement for ease of placement of materials.

- A higher slump may be required for large crater repair and full-slab replacements due to the larger volume of material to be worked.
- No slump data to date exist on materials tested at ERDC, but it is recommended that future tests include this test; however, no recommendation should be set without further investigation.

Additional ETL modifications

Based on the results of this investigation the following additional changes to ETL 08-02 (AFCESA 2008a) are recommended:

Testing frequency

Upon review of other repair material certification programs, a change to the material certification program to set a testing schedule is recommended. The following conclusions and recommendations are provided:

- It is recommended that the Repair Material Certification Program include retest of all products every 5 years, similar to NTEP requirements for highways. Unless the material vendor discloses a reformulation of material and new mixing instructions, identical mixing procedures to previous tests should be followed.
- Large differences in materials tested under identical conditions from the same laboratory indicate material reformulation. Because reformulation of materials or changes in component chemistry are common for these product types, retest of materials following identical laboratory procedures are recommended.

Title

The title should be changed from “Testing Protocol for Rigid Spall Repair Materials” to “Testing Protocol for Cementitious Repair Materials” as testing requirements have been modified based on repair size or type.

General reporting

All materials evaluated in future testing should be summarized in fact sheets similar to those presented in the appendices. A new requirement to detail the weights or volumes of the constituent materials under “Mixing Method” is recommended.

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Appendix A: AFRL FY07 Cementitious Repair Material Fact Sheets

Rigid Repair Material Evaluation Report

Product Name: Futura 15		**Material Description:** Proprietary Cement		
Manufacturer Name and Contact Information: W.R. Meadows , Inc.				
P.O. Box 388, Hampshire, IL 60140-0338; 800-342-5976; www.wrmeadows.com				
NSN/GSA#:				
Evaluated by: AFRL/RXQD				
Date: FY07		**Result: (Pass or Fail):** Fail[1]		
Result Details				
ASTM Test	**Criteria**	**Manufacturer Test Result**	**Laboratory Test Result**	**Pass/Fail**
C 39 Compressive Strength	≥ 3,000 psi at test age of 2 hr ≥ 5,000 psi at test age of 1 day	3,500 psi [2] 6,000 psi [2]	1,960 psi 4,680 psi	Fail
C 78 Flexural Strength	≥ 350 psi at test age of 2 hr	N/A	475 psi	Pass
C 882 Bond Strength	≥ 850 psi to OPC ≥ 1,000 psi to self Test age of 1 day for both conditions	2,370 psi to self	325 psi to OPC	Fail
C469 Static Modulus of Elasticity	≤ $3x10^6$ psi test at age of 2 hr ≤ $4x10^6$ psi test at age of 3 days	N/A	N/A N/A	N/A
C 531 Volumetric Expansion	≤ 7 x 10^{-6} in/in/ºF test at age of 3 days	N/A	N/A	N/A
C 157 Volumetric Expansion	< 0.03% test begins at age of 4 days	N/A	N/A	N/A
C 1581 Shrinkage Potential	≤ 40 microstrain at 14 days and no cracking at 28 days	N/A	N/A	N/A
C 666 Freeze-Thaw Resistance	No requirement at this time	N/A	N/A	N/A
C 191 Time of Setting	No requirement at this time	14-18 min (initial) 20-25 min (final)	N/A N/A	N/A

Additional Product Information

Shelf life/Storage conditions

Shelf life of bagged materials is 12 months when stored on pallets in a dry, cool area.

Packaging and yield

Material is packaged in 50 lb bags each yielding 0.43 cu. ft. Extended with 25 lb of aggregate yields 0.60 cu. ft.

Additional material requirements

Can by extended by adding up to 50% aggregate by weight. Aggregate extension recommended for repairs greater than 2 inches in depth. Do not add any admixtures.

Mixing method/equipment

Use mortar type mixer. Mix only complete bags.

Cleanup

Wash all equipment with water immediately after use.

Safety Hazards

See manufacturer MSDS for details.

Unique test conditions

[1]Not all laboratory protocol tests were conducted on this material.
[2]Manufacturer's data per ASTM C 109 (50 mm mortar cubes).

Handling/Use Notes

Rigid Repair Material Evaluation Report

Product Name: HD-50	**Material Description:** Proprietary Cement
Manufacturer Name and Contact Information: Dayton Superior	
4226 Kansas Avenue, Kansas City, KS 66016; 913-233-1750; www.daytonsuperiorchemical.com	
NSN/GSA#:	
Evaluated by: AFRL/RXQD	
Date: FY07	**Result: (Pass or Fail):** Fail[1]

Result Details

ASTM Test	Criteria	Manufacturer Test Result	Laboratory Test Result	Pass/Fail
C 39 Compressive Strength	≥ 3,000 psi at test age of 2 hr ≥ 5,000 psi at test age of 1 day	3,500 psi (3 hr)[2] 6,145 psi (1 day)[2]	2,850 psi 4,580 psi	Fail
C 78 Flexural Strength	≥ 350 psi at test age of 2 hr	N/A	650 psi	Pass
C 882 Bond Strength	≥ 850 psi to OPC ≥ 1,000 psi to self Test age of 1 day for both conditions	1,950 psi to self	1,150 psi to OPC	Pass
C469 Static Modulus of Elasticity	≤ $3x10^6$ psi test at age of 2 hr ≤ $4x10^6$ psi test at age of 3 days	N/A	N/A N/A	N/A
C 531 Volumetric Expansion	≤ 7×10^{-6} in/in/°F test at age of 3 days	N/A	N/A	N/A
C 157 Volumetric Expansion	< 0.03% test begins at age of 4 days	N/A	N/A	N/A
C 1581 Shrinkage Potential	≤ 40 microstrain at 14 days and no cracking at 28 days	N/A	N/A	N/A
C 666 Freeze-Thaw Resistance	No requirement at this time	N/A	N/A	N/A
C 191 Time of Setting	No requirement at this time	N/A	N/A	N/A

Additional Product Information

Shelf life/Storage conditions

Shelf life is approximately 1 year. Store on pallets in a cool, dry area and free from direct sunlight.

Packaging and yield

Material is packaged in 50 lb bags yielding 0.42 cu. ft. The yield is 0.60 cu. ft. when extended with 30 lbs. of 3/8-inch pea gravel.

Additional material requirements

Can be extended by adding up to 60% by weight of 3/8-inch pea gravel. Use of a bonding agent may be required.

Mixing method/equipment

Can be mixed in a 5 gal. bucket using a drill and paddle or in a mortar mixer, preferably with rubber-tipped blades. Mix until material is free of lumps (approximately 3−5 min.)

Cleanup

Wash all equipment with water immediately after use.

Safety Hazards

See manufacturer MSDS for details.

Unique test conditions

[1]Not all laboratory protocol tests were conducted on this material.
[2]Manufacturer's data per ASTM C 109 (50 mm mortar cubes).

Handling/Use Notes

Do not re-temper after initial mixing.

Rigid Repair Material Evaluation Report

Product Name: Pavemend 15.0		**Material Description:** Proprietary Cement		
Manufacturer Name and Contact Information: Ceratech, Inc.				
1500 North Beaurgard St., Suite 320, Alexandria, VA 22311; 800-581-8397; www.ceratechinc.com				
NSN/GSA#:				
Evaluated by: AFRL/RXQD				
Date: FY07		**Result: (Pass or Fail):** Fail[1]		
Result Details				
ASTM Test	**Criteria**	**Manufacturer Test Result**	**Laboratory Test Result**	**Pass/Fail**
C 39 Compressive Strength	≥ 3,000 psi at test age of 2 hr ≥ 5,000 psi at test age of 1 day	2,700 psi (1 hr)[2] 4,230 psi (1 day)[2]	460 psi 1,820 psi	Fail
C 78 Flexural Strength	≥ 350 psi at test age of 2 hr	N/A	400 psi	Pass
C 882 Bond Strength	≥ 850 psi to OPC ≥ 1,000 psi to self Test age of 1 day for both conditions	1,100 psi to self	515 psi to OPC	Fail
C469 Static Modulus of Elasticity	≤ $3x10^6$ psi test at age of 2 hr ≤ $4x10^6$ psi test at age of 3 days	N/A	N/A N/A	N/A
C 531 Volumetric Expansion	≤ 7×10^{-6} in/in/ºF test at age of 3 days	N/A	N/A	N/A
C 157 Volumetric Expansion	< 0.03% test begins at age of 4 days	N/A	N/A	N/A
C 1581 Shrinkage Potential	≤ 40 microstrain at 14 days and no cracking at 28 days	N/A	N/A	N/A
C 666 Freeze-Thaw Resistance	No requirement at this time	N/A	N/A	N/A
C 191 Time of Setting	No requirement at this time	N/A	N/A	N/A

Additional Product Information

Shelf life/Storage conditions

Shelf life is 1 year in original unopened bag or 3 years in original unopened bucket.

Packaging and yield

Material is packaged in 11 lb bag yielding 0.12 cu. ft., 45 lb bag yielding 0.42 cu. ft., or 45 lb bucket yielding 0.42 cu. ft.

Additional material requirements

Cannot be extended with aggregate.

Mixing method/equipment

Can be mixed with drill and paddle or in a grout mixer. Do not mix in a rotating drum concrete mixer. Mix until a critical mix temperature of 95°F is reached. Never mix for less than 2½ min.

Cleanup

Wash all equipment with water immediately after use.

Safety Hazards

See manufacturer MSDS for details.

Unique test conditions

[1]Not all laboratory protocol tests were conducted on this material.
[2]Manufacturer's data per ASTM C 109 (50 mm mortar cubes).

Handling/Use Notes

Use thermal gun to measure mix temperature

Rigid Repair Material Evaluation Report

Product Name: Pavemend TR **Material Description:** Proprietary Cement

Manufacturer Name and Contact Information: Ceratech, Inc.

1500 North Beaurgard St., Suite 320, Alexandria, VA 22311; 800-581-8397; www.ceratechinc.com

NSN/GSA#:

Evaluated by: AFRL/RXQD

Date: FY07 **Result: (Pass or Fail):** Fail[1]

Result Details

ASTM Test	Criteria	Manufacturer Test Result	Laboratory Test Result	Pass/Fail
C 39 Compressive Strength	≥ 3,000 psi at test age of 2 hr ≥ 5,000 psi at test age of 1 day	3,000 psi (1 hr)[2] 5,352 psi (1 day)[2]	280 psi 1,860 psi	Fail
C 78 Flexural Strength	≥ 350 psi at test age of 2 hr	N/A	Could not de-mold	Fail
C 882 Bond Strength	≥ 850 psi to OPC ≥ 1,000 psi to self Test age of 1 day for both conditions	1,270 psi to self	515 psi to OPC	Fail
C469 Static Modulus of Elasticity	≤ $3x10^6$ psi test at age of 2 hr ≤ $4x10^6$ psi test at age of 3 days	N/A	N/A N/A	N/A
C 531 Volumetric Expansion	≤ 7×10^{-6} in/in/°F test at age of 3 days	N/A	N/A	N/A
C 157 Volumetric Expansion	< 0.03% test begins at age of 4 days	N/A	N/A	N/A
C 1581 Shrinkage Potential	≤ 40 microstrain at 14 days and no cracking at 28 days	N/A	N/A	N/A
C 666 Freeze-Thaw Resistance	No requirement at this time	N/A	N/A	N/A
C 191 Time of Setting	No requirement at this time	N/A	N/A	N/A

Additional Product Information

Shelf life/Storage conditions

Shelf life is 1 year in original unopened bag or 3 years in original unopened bucket.

Packaging and yield

Material is packaged in 12 lb bag yielding 0.12 cu. ft., 47 lb bag yielding 0.43 cu. ft., or 47 lb bucket yielding 0.43 cu. ft.

Additional material requirements

Can be extended up to 100% by mass with aggregate.

Mixing method/equipment

Can be mixed in a bucket with drill and paddle or in a rotating drum concrete mixer (for aggregate extension). Mix until a critical mix temperature of 90°F is reached. Never mix for less than 3 min. A chart is provided by the manufacturer for temperature-dependent mix times when using a drum mixer.

Cleanup

Wash all equipment with water immediately after use.

Safety Hazards

See manufacturer MSDS for details.

Unique test conditions

[1]Not all laboratory protocol tests were conducted on this material.
[2]Manufacturer's data per ASTM C 109 (50 mm mortar cubes).

Handling/Use Notes

Rigid Repair Material Evaluation Report

Product Name: Pavemend VR **Material Description:** Proprietary Cement

Manufacturer Name and Contact Information: Ceratech, Inc.

1500 North Beaurgard St., Suite 320, Alexandria, VA 22311; 800-581-8397; www.ceratechinc.com

NSN/GSA#:

Evaluated by: AFRL/RXQD

Date: FY07 **Result: (Pass or Fail):** Fail[1]

Result Details

ASTM Test	Criteria	Manufacturer Test Result	Laboratory Test Result	Pass/Fail
C 39 Compressive Strength	≥ 3,000 psi at test age of 2 hr ≥ 5,000 psi at test age of 1 day	4,300 psi (3 hr)[2] 4,800 psi (1 day)[2]	405 psi 3,160 psi	Fail
C 78 Flexural Strength	≥ 350 psi at test age of 2 hr	N/A	310 psi	Fail
C 882 Bond Strength	≥ 850 psi to OPC ≥ 1,000 psi to self Test age of 1 day for both conditions	1,640 psi to self	595 psi to OPC	Fail
C469 Static Modulus of Elasticity	≤ $3x10^6$ psi test at age of 2 hr ≤ $4x10^6$ psi test at age of 3 days	N/A	N/A N/A	N/A
C 531 Volumetric Expansion	≤ 7 x 10^{-6} in/in/ºF test at age of 3 days	N/A	N/A	N/A
C 157 Volumetric Expansion	< 0.03% test begins at age of 4 days	N/A	N/A	N/A
C 1581 Shrinkage Potential	≤ 40 microstrain at 14 days and no cracking at 28 days	N/A	N/A	N/A
C 666 Freeze-Thaw Resistance	No requirement at this time	N/A	N/A	N/A
C 191 Time of Setting	No requirement at this time	N/A	N/A	N/A

Additional Product Information

Shelf life/Storage conditions

Shelf life is 3 years in original unopened bucket.

Packaging and yield

Material is packaged in a 2 gal bucket yielding 0.14 cu. ft. or a 5 gal bucket yielding 0.43 cu. ft.

Additional material requirements

Can be extended up to 100% by weight with aggregate.

Mixing method/equipment

Mix in a bucket with drill and paddle. Mix until a critical mix temperature of 80°F is reached. Never mix for less than 3 min.

Cleanup

Wash all equipment with water immediately after use.

Safety Hazards

See manufacturer MSDS for details.

Unique test conditions

[1]Not all laboratory protocol tests were conducted on this material.
[2]Manufacturer's data per ASTM C 109 (50 mm mortar cubes).

Handling/Use Notes

Not recommended for surface temperatures about 120°F or below 40°F.

Rigid Repair Material Evaluation Report

Product Name: Pave Patch - 3000		**Material Description:** Proprietary Cement		
Manufacturer Name and Contact Information: CONSPEC Marketing and Manufacturing Co.				
4226 Kansas Avenue, Kansas City, KS 66106; 800-348-7351; www.conspecmkt.com				
NSN/GSA#:				
Evaluated by: AFRL/RXQD				
Date: FY07		**Result: (Pass or Fail):** Fail[1]		
Result Details				
ASTM Test	**Criteria**	**Manufacturer Test Result**	**Laboratory Test Result**	**Pass/Fail**
C 39 Compressive Strength	≥ 3,000 psi at test age of 2 hr ≥ 5,000 psi at test age of 1 day	3,000 psi (1 hr)[2] 5,500 psi (1 day)[2]	40 psi 2,650 psi	Fail
C 78 Flexural Strength	≥ 350 psi at test age of 2 hr	N/A	Prisms broke during de-molding	Fail
C 882 Bond Strength	≥ 850 psi to OPC ≥ 1,000 psi to self Test age of 1 day for both conditions	1,000 psi to self	2,700 psi to OPC	Pass
C469 Static Modulus of Elasticity	≤ $3x10^6$ psi test at age of 2 hr ≤ $4x10^6$ psi test at age of 3 days	N/A	N/A N/A	N/A
C 531 Volumetric Expansion	≤ 7×10^{-6} in/in/ºF test at age of 3 days	N/A	N/A	N/A
C 157 Volumetric Expansion	< 0.03% test begins at age of 4 days	N/A	N/A	N/A
C 1581 Shrinkage Potential	≤ 40 microstrain at 14 days and no cracking at 28 days	N/A	N/A	N/A
C 666 Freeze-Thaw Resistance	No requirement at this time	N/A	N/A	N/A
C 191 Time of Setting	No requirement at this time	N/A	N/A N/A	N/A

Additional Product Information

Shelf life/Storage conditions

Shelf life is up to 12 months. Bagged product should be stored in a cool, dry interior area.

Packaging and yield

Material is packaged in 50 lb bags yielding 0.41 cu. ft.

Additional material requirements

Use of a bonding agent may be required.

Mixing method/equipment

Mix for 2 to 3 minutes. Use a mortar mixer with rubber-tipped blades or mix in a 5 gal. bucket using heavy duty drill with paddle.

Cleanup

Wash all equipment with water immediately after use.

Safety Hazards

See manufacturer MSDS for details.

Unique test conditions

[1]Not all laboratory protocol tests were conducted on this material.
[2]Manufacturer's data per ASTM C 109 (50 mm mortar cubes).

Handling/Use Notes

Adequate placing and finishing equipment and material should be available for continuous placement of the

Rigid Repair Material Evaluation Report

Product Name: Premium Patch 200 **Material Description:** Proprietary Cement

Manufacturer Name and Contact Information: Pre-Blend Products, Inc.

100 Ben Fairless Drive, Fairless Hills, PA 19030; 215-295-6004; www.preblend.com

NSN/GSA#:

Evaluated by: AFRL/RXQD

Date: FY07 **Result: (Pass or Fail):** Fail[1]

Result Details

ASTM Test	Criteria	Manufacturer Test Result	Laboratory Test Result	Pass/Fail
C 39 Compressive Strength	≥ 3,000 psi at test age of 2 hr ≥ 5,000 psi at test age of 1 day	2,650 psi (1 hr)[2] 5,400 psi (1 day)[2]	3,730 psi 3,330 psi	Pass
C 78 Flexural Strength	≥ 350 psi at test age of 2 hr	N/A	690 psi	Pass
C 882 Bond Strength	≥ 850 psi to OPC ≥ 1,000 psi to self Test age of 1 day for both conditions	1,500 psi to self	1,040 psi to OPC	Pass
C469 Static Modulus of Elasticity	≤ $3x10^6$ psi test at age of 2 hr ≤ $4x10^6$ psi test at age of 3 days	N/A	N/A N/A	N/A
C 531 Volumetric Expansion	≤ 7 x 10^{-6} in/in/ºF test at age of 3 days	N/A	N/A	N/A
C 157 Volumetric Expansion	< 0.03% test begins at age of 4 days	N/A	N/A	N/A
C 1581 Shrinkage Potential	≤ 40 microstrain at 14 days and no cracking at 28 days	N/A	N/A	N/A
C 666 Freeze-Thaw Resistance	No requirement at this time	N/A	N/A	N/A
C 191 Time of Setting	No requirement at this time	18 min (initial) 20 min (final)	N/A	N/A

Additional Product Information

Shelf life/Storage conditions

Shelf life is 12 months in original unopened container. Keep in cool, dry place unexposed to sunlight.

Packaging and yield

Material is packaged in 50 lb bags yielding 0.43 cu. ft. When extended with 30 lbs of 3/8 inch pea gravel, the yield is 0.61 cu. ft.

Additional material requirements

Can be extended by adding up to 60% by weight clean 3/8-inch dry pea gravel. Extending with aggregate required for repairs deeper than 2 inches.

Mixing method/equipment

Can be mixed in a mortar mixer or by using a paddle attached to a heavy duty drill. Mix for 2 to 3 minutes to a lump free consistency.

Cleanup

Wash all equipment with water immediately after use.

Safety Hazards

See manufacturer MSDS for details.

Unique test conditions

[1]Not all laboratory protocol tests were conducted on this material.
[2]Manufacturer's data per ASTM C 109 (50 mm mortar cubes).

Rigid Repair Material Evaluation Report

Product Name: Rapid Set® DOT Mix **Material Description:** Calcium sulfoaluminate

Manufacturer Name and Contact Information: CTS Cement Manufacturing Corporation

11065 Knott Avenue, Suite A, Cypress, CA 90630; 800-929-3030; http://www.ctscement.com

NSN/GSA#: NSN 5610-01-564-7710

Evaluated by: ERDC/GSL

Date: FY06 **Result: (Pass or Fail):** Pass[1]

Result Details

ASTM Test	Criteria	Manufacturer Test Result	Laboratory Test Result	Pass/Fail
C 39 Compressive Strength	≥ 3,000 psi at test age of 2 hr ≥ 5,000 psi at test age of 1 day	4,650 psi (1 day) 5,500 psi (28 day)	7,270 psi (2 hr) 9,240 psi (24 hr)	Pass
C 78 Flexural Strength	≥ 350 psi at test age of 2 hr	N/A	805 psi (2 hr)	Pass
C 882 Bond Strength	≥ 850 psi to OPC ≥ 1,000 psi to self Test age of 1 day for both conditions	2,000 psi N/A	1,470 psi to OPC	Pass
C469 Static Modulus of Elasticity	≤ $3x10^6$ psi test at age of 2 hr ≤ $4x10^6$ psi test at age of 3 days	N/A	N/A	N/A
C 531 Volumetric Expansion	≤ 7 x 10^{-6} in/in/ºF test at age of 3 days	N/A	N/A	N/A
C 157 Volumetric Expansion	< 0.03% test begins at age of 4 days	N/A	N/A	N/A
C 1581 Shrinkage Potential	≤ 40 microstrain at 14 days and no cracking at 28 days	N/A	N/A	N/A
C 666 Freeze-Thaw Resistance	No requirement at this time	100%	N/A	N/A
C 191 Time of Setting	No requirement at this time	17 min (initial) 20 min (final)	N/A	N/A

Additional Product Information

Shelf life/Storage conditions

Store material in a dry location, not in direct contact with the ground. It is recommended that fine and coarse materials used to extend mixes be covered and stored on a clean, solid, and dry surface.

Packaging and yield

50 lb bag yield is 2 ft^3 when extended per vendor instructions (also available in supersack quantities).

Additional material requirements

Extend with 100 lb sand and 100 lb stone (3/8 to 3/4 in).

Mixing method/equipment

Rock and tilt revolving drum mixer. See manufacturer guide for details.

Cleanup

Wash all equipment with water immediately after use.

Safety Hazards

See manufacturer MSDS for details.

Unique test conditions

[1]Not all laboratory protocol tests were conducted on this material. This material performed well in field tests as a full-depth repair.

Handling/Use Notes

Use standard concrete mixing equipment with caution due to fast set time.

Rigid Repair Material Evaluation Report

Product Name: SikaQuick 2500 **Material Description:** Proprietary Cement

Manufacturer Name and Contact Information: Sika Corporation

201 Polito Avenue, Lyndhurst, NJ 07071; 800-933-7452; www.sikaconstruction.com

NSN/GSA#: NSN 5610-01-564-7710

Evaluated by: AFRL/RXQD

Date: FY07 **Result: (Pass or Fail):** Pass[1]

Result Details

ASTM Test	Criteria	Manufacturer Test Result	Laboratory Test Result	Pass/Fail
C 39 Compressive Strength	≥ 3,000 psi at test age of 2 hr ≥ 5,000 psi at test age of 1 day	3,000 psi (1 hr) 4,500 psi (1 day)	5,790 psi 6,550 psi	Pass
C 78 Flexural Strength	≥ 350 psi at test age of 2 hr	N/A	795 psi	Pass
C 882 Bond Strength	≥ 850 psi to OPC ≥ 1,000 psi to self Test age of 1 day for both conditions	1,800 psi to self	1770 psi to OPC	Pass
C469 Static Modulus of Elasticity	≤ $3x10^6$ psi test at age of 2 hr ≤ $4x10^6$ psi test at age of 3 days	N/A	N/A N/A	N/A
C 531 Volumetric Expansion	≤ 7 x 10^{-6} in/in/°F test at age of 3 days	N/A	N/A	N/A
C 157 Volumetric Expansion	< 0.03% test begins at age of 4 days	N/A	N/A	N/A
C 1581 Shrinkage Potential	≤ 40 microstrain at 14 days and no cracking at 28 days	N/A	N/A	N/A
C 666 Freeze-Thaw Resistance	No requirement at this time	N/A	N/A	N/A
C 191 Time of Setting	No requirement at this time	N/A	N/A	N/A

Additional Product Information

Shelf life/Storage conditions

Shelf life is 1 year in original, unopened bag.

Packaging and yield

Material is packaged in 50 lb bags yielding 0.43 cu. ft. When extended with 25 to 30 lbs of aggregate, the yield is 0.60 to 0.63 cu. ft.

Additional material requirements

Can be extended by adding up to 25 - 30 lb of aggregate per bag. Extending with aggregate recommended for repairs greater than 1 inch in depth.

Mixing method/equipment

Mix in an appropriate sized mortar mixer.

Cleanup

Wash all equipment with water immediately after use.

Safety Hazards

See manufacturer MSDS for details.

Unique test conditions

[1]Not all laboratory protocol tests were conducted on this material.

Handling/Use Notes

Rigid Repair Material Evaluation Report

Product Name: ThoRoc 10-61	**Material Description:** Proprietary Cement
Manufacturer Name and Contact Information: BASF Building Systems	
869 Valley Park Dr., Shakopee, MN 55379; 952-496-6000; http://www.buildingsystems.basf.com/	
NSN/GSA#: NSN 5610-01-564-7710	
Evaluated by: AFRL/RXQD	
Date: FY07	**Result: (Pass or Fail):** Pass[1]

Result Details

ASTM Test	Criteria	Manufacturer Test Result	Laboratory Test Result	Pass/Fail
C 39 Compressive Strength	≥ 3,000 psi at test age of 2 hr ≥ 5,000 psi at test age of 1 day	N/A 7,400 (28 day)	4,480 psi (3 hr) 6,070 psi	Pass
C 78 Flexural Strength	≥ 350 psi at test age of 2 hr	N/A	705	Pass
C 882 Bond Strength	≥ 850 psi to OPC ≥ 1,000 psi to self Test age of 1 day for both conditions	2,300 psi N/A	1,120 psi	Pass
C469 Static Modulus of Elasticity	≤ $3x10^6$ psi test at age of 2 hr ≤ $4x10^6$ psi test at age of 3 days	N/A 4.4 $x10^6$ (28 day)	N/A	N/A
C 531 Volumetric Expansion	≤ 7 x 10^{-6} in/in/°F test at age of 3 days	7 x 10^{-6} in/in/°F	N/A	N/A
C 157 Volumetric Expansion	< 0.03% test begins at age of 4 days	N/A	N/A	N/A
C 1581 Shrinkage Potential	≤ 40 microstrain at 14 days and no cracking at 28 days	N/A	N/A	N/A
C 666 Freeze-Thaw Resistance	No requirement at this time	100%	N/A	N/A
C 191 Time of Setting	No requirement at this time	16 min (initial) 28 min (final)	N/A	N/A

Additional Product Information

Shelf life/Storage conditions

Shelf life of bagged materials is 1 year if stored in a cool dry place.

Packaging and yield

50 lb bags. Yield when extended 50% by weight aggregate is 0.57 cf.

Additional material requirements

Requires extension for repairs >2 in. depth. Extend with 50% by weight with 3/8-in. pea gravel.

Mixing method/equipment

Mortar mixer or drill and paddle. See manufacturer guide for details.

Cleanup

Wash all equipment with water immediately after use.

Safety Hazards

See manufacturer MSDS for details.

Unique test conditions

[1]Not all laboratory protocol tests were conducted on this material. This material performed well in field tests for full-depth repairs.

Handling/Use Notes

Use standard concrete mixing equipment with caution due to fast set time.

Rigid Repair Material Evaluation Report

Product Name: Versaspeed	**Material Description:** Proprietary Cement
Manufacturer Name and Contact Information: The Euclid Chemical Company	
19218 Redwood Road, Cleveland, OH 44110; 800-321-7628; www.euclidchemical.com	
NSN/GSA#:	
Evaluated by: AFRL/RXQD	
Date: FY07	**Result: (Pass or Fail):** Fail[1]

Result Details

ASTM Test	Criteria	Manufacturer Test Result	Laboratory Test Result	Pass/Fail
C 39 Compressive Strength	≥ 3,000 psi at test age of 2 hr ≥ 5,000 psi at test age of 1 day	3,500 psi (3 hr)[2] 5,500 psi (1 day)[2]	150 psi 4,270 psi	Fail
C 78 Flexural Strength	≥ 350 psi at test age of 2 hr	N/A	Prisms broke on demolding	Fail
C 882 Bond Strength	≥ 850 psi to OPC ≥ 1,000 psi to self Test age of 1 day for both conditions	2,550 psi to self	1,290 psi to OPC	Pass
C469 Static Modulus of Elasticity	≤ $3x10^6$ psi test at age of 2 hr ≤ $4x10^6$ psi test at age of 3 days	N/A	N/A N/A	N/A
C 531 Volumetric Expansion	≤ 7×10^{-6} in/in/°F test at age of 3 days	N/A	N/A	N/A
C 157 Volumetric Expansion	< 0.03% test begins at age of 4 days	N/A	N/A	N/A
C 1581 Shrinkage Potential	≤ 40 microstrain at 14 days and no cracking at 28 days	N/A	N/A	N/A
C 666 Freeze-Thaw Resistance	No requirement at this time	N/A	N/A	N/A
C 191 Time of Setting	No requirement at this time	N/A	N/A	N/A

Additional Product Information

Shelf life/Storage conditions

Shelf life is 2 years in original, unopened package.

Packaging and yield

Material is packaged in 50 lb bags yielding 0.37 cu. ft. When extended with 25 lb of aggregate, the yield is 0.52 cu. ft.

Additional material requirements

Can be extended by adding up to 25 lb of aggregate per bag.

Mixing method/equipment

Small quantities can be mixed with a heavy duty drill and paddle. A paddle-type mortar mixer is recommended for larger jobs.

Cleanup

Wash all equipment with water immediately after use.

Safety Hazards

See manufacturer MSDS for details.

Unique test conditions

[1]Not all laboratory protocol tests were conducted on this material.
[2]Manufacturer's data per ASTM C 109 (50 mm mortar cubes).

Handling/Use Notes

Extending with aggregate may alter engineering properties.

Appendix B: ERDC FY07 Cementitious Repair Material Fact Sheets

Rigid Repair Material Evaluation Report

Product Name: Express Repair		**Material Description:** Proprietary Cement		
Manufacturer Name and Contact Information: Tamms Industries, Inc.				
3835 State Route 72, Kirkland, IL 60146, 800-862-2667; FAX: 815-522-2323 ; www.tamms.com				
NSN/GSA#:				
Evaluated by: ERDC/GSL				
Date: FY07		**Result: (Pass or Fail):** Fail[1]		
Result Details				
ASTM Test	**Criteria**	**Manufacturer Test Result**	**Laboratory Test Result**	**Pass/Fail**
C 39 Compressive Strength	≥ 3,000 psi at test age of 2 hr ≥ 5,000 psi at test age of 1 day	N/A	3,250 psi 4,023 psi	Pass Fail
C 78 Flexural Strength	≥ 350 psi at test age of 2 hr	N/A	N/A	N/A
C 882 Bond Strength	≥ 850 psi to OPC ≥ 1,000 psi to self Test age of 1 day for both conditions	N/A	720 psi 960 psi	Fail Fail
C469 Static Modulus of Elasticity	≤ $3x10^6$ psi test at age of 2 hr ≤ $4x10^6$ psi test at age of 3 days	N/A	N/A	
C 531 Volumetric Expansion	≤ 7 x 10^{-6} in/in/ºF test at age of 3 days	N/A	N/A	N/A
C 157 Volumetric Expansion	< 0.03% test begins at age of 4 days	N/A	N/A	N/A
C 1581 Shrinkage Potential	≤ 40 microstrain at 14 days and no cracking at 28 days	N/A	No Cracking	Pass
C 666 Freeze-Thaw Resistance	No requirement at this time	N/A	N/A	N/A
C 191 Time of Setting	No requirement at this time	N/A	55 min (initial) 57 min (final)	N/A

Additional Product Information

Shelf life/Storage conditions

Shelf life of bagged materials is 1 year if stored in a cool dry place.

Packaging and yield

50 lb bags. Yield 0.42 cubic feet. May be extended with 50 lb of 3/8-in. pea gravel per bag to yield 0.75 cubic feet.

Additional material requirements

Concrete mix requires aggregate extension.

Mixing method/equipment

Mortar mixer, drill and paddle, or standard concrete mixer. See manufacturer guide for details.

Cleanup

Wash all equipment with water immediately after use.

Safety Hazards

See manufacturer MSDS for details.

Unique test conditions

[1]Not all laboratory protocol tests were conducted on this material. This material performed poorly in field tests for full-depth repairs.

Handling/Use Notes

Use standard concrete mixing equipment with caution due to fast set time.

Rigid Repair Material Evaluation Report

Product Name: Pavemend SL	**Material Description:** Magnesium Phosphate
Manufacturer Name and Contact Information: Ceratech, Inc.	
1500 N. Beaurgard St. Suite 320, Alexandria, Virginia 22311; 800-341-2600; www.ceratechinc.com	
NSN/GSA#: NSN 5610-01-564-7710	
Evaluated by: ERDC/GSL	
Date: FY07	**Result: (Pass or Fail):** Pass[1]

Result Details

ASTM Test	Criteria	Manufacturer Test Result	Laboratory Test Result	Pass/Fail
C 39 Compressive Strength	≥ 3,000 psi at test age of 2 hr ≥ 5,000 psi at test age of 1 day	N/A	3,100 psi 3,880 psi	Pass
C 78 Flexural Strength	≥ 350 psi at test age of 2 hr	660 psi (7 day) neat	N/A	N/A
C 882 Bond Strength	≥ 850 psi to OPC ≥ 1,000 psi to self Test age of 1 day for both conditions	1,613 psi N/A	1,360 psi 1,880 psi	Pass
C469 Static Modulus of Elasticity	≤ $3x10^6$ psi test at age of 2 hr ≤ $4x10^6$ psi test at age of 3 days	2.21 $x10^6$ psi (28 day)	N/A	N/A
C 531 Volumetric Expansion	≤ 7 x 10^{-6} in/in/°F test at age of 3 days	N/A	N/A	N/A
C 157 Volumetric Expansion	< 0.03% test begins at age of 4 days	-0.033% (28 days) neat	N/A	N/A
C 1581 Shrinkage Potential	≤ 40 microstrain at 14 days and no cracking at 28 days	N/A	N/A	N/A
C 666 Freeze-Thaw Resistance	No requirement at this time	N/A	N/A	N/A
C 191 Time of Setting	No requirement at this time	8 min (final)	11 min (initial) 17 min (final)	N/A

Additional Product Information

Shelf life/Storage conditions

3 years in buckets.

Packaging and yield

45 lb 5 gallon buckets. Yield when extended 75% by weight aggregate is 0.72 cf.

Additional material requirements

Requires extension for full-depth repairs. Extend with 75% by weight with 3/8-in. pea gravel or ½-in. stone.

Mixing method/equipment

Drill and paddle attachment in bucket. See manufacturer guide for details.

Cleanup

Wash all equipment with water immediately after use.

Safety Hazards

See manufacturer MSDS for details.

Unique test conditions

[1]This material met most laboratory minimum requirements, but the material failed in FY06 field trials for full-depth repairs. This material was retested in FY07 with fair results, but no new laboratory data are available. At the time of field testing, the material was not commercially available.

Handling/Use Notes

This material sets very quickly. Because this material must be mixed in single buckets, more time is required to

Rigid Repair Material Evaluation Report

Product Name: Pavemend SLQ		**Material Description:** Magnesium Phosphate	
Manufacturer Name and Contact Information: Ceratech, Inc.			
1500 N. Beaurgard St. Suite 320, Alexandria, Virginia 22311; 800-341-2600; www.ceratechinc.com			
NSN/GSA#: NSN 5610-01-564-7710			
Evaluated by: ERDC/GSL			
Date: FY07		**Result: (Pass or Fail):** Pass[1]	
Result Details			
ASTM Test	**Criteria**	**Manufacturer Test Result**	**Laboratory Test Result**	**Pass/Fail**
C 39 Compressive Strength	≥ 3,000 psi at test age of 2 hr ≥ 5,000 psi at test age of 1 day	2,656 (1 hr) 4,524 (1 day)	2,630 psi 3,590 psi	Fail
C 78 Flexural Strength	≥ 350 psi at test age of 2 hr	600 psi (7 day) neat	N/A	N/A
C 882 Bond Strength	≥ 850 psi to OPC ≥ 1,000 psi to self Test age of 1 day for both conditions	2,648 psi N/A	N/A	Fail
C469 Static Modulus of Elasticity	≤ $3x10^6$ psi test at age of 2 hr ≤ $4x10^6$ psi test at age of 3 days	N/A	N/A	N/A
C 531 Volumetric Expansion	≤ 7 x 10^{-6} in/in/ºF test at age of 3 days	N/A	N/A	N/A
C 157 Volumetric Expansion	< 0.03% test begins at age of 4 days	0.0085% (28 days) neat	N/A	N/A
C 1581 Shrinkage Potential	≤ 40 microstrain at 14 days and no cracking at 28 days	N/A	N/A	N/A
C 666 Freeze-Thaw Resistance	No requirement at this time	99.6% (neat)	N/A	N/A
C 191 Time of Setting	No requirement at this time	3 min (initial) 6 min (final)	6 min (initial) 7.5 min (final)	N/A

Additional Product Information

Shelf life/Storage conditions

3 years in buckets.

Packaging and yield

46 lb 5 gallon buckets. Yield when extended 75% by weight aggregate is 0.72 cf.

Additional material requirements

Requires extension for full-depth repairs. Extend with 75% by weight with 3/8-in. pea gravel or ½-in. stone.

Mixing method/equipment

Drill and paddle attachment in bucket. See manufacturer guide for details.

Cleanup

Wash all equipment with water immediately after use.

Safety Hazards

See manufacturer MSDS for details.

Unique test conditions

[1]Although this material did not meet minimum requirements for rigid repair materials, it performed well as temporary repairs in recent field trials.

Handling/Use Notes

This material sets very quickly. Recent tests with this material identified expansion problems. For a temporary repair, this material performs very well. Surface finish may be difficult to achieve with this material. Because this material must be mixed in single buckets, more time is required to place multiple buckets of material than with

Rigid Repair Material Evaluation Report

Product Name: Rapid Set® Concrete Mix	**Material Description:** Proprietary Cement
Manufacturer Name and Contact Information: CTS Cement Manufacturing Corporation	
Mr. Chris Davis: 11065 Knott Avenue, Suite A, Cypress, CA 90630; 714-379-8270; www.ctscement.com	
NSN/GSA#: NSN 5610-01-564-7710	
Evaluated by: ERDC/GSL	
Date: FY07	**Result: (Pass or Fail):** Pass[1]

Result Details

ASTM Test	Criteria	Manufacturer Test Result	Laboratory Test Result	Pass/Fail
C 39 Compressive Strength	≥ 3,000 psi at test age of 2 hr ≥ 5,000 psi at test age of 1 day	2,800 psi (1 hr) 5,000 psi (7 day)	5,080 psi 6,610 psi	Pass
C 78 Flexural Strength	≥ 350 psi at test age of 2 hr	420 psi	520 psi	Pass
C 882 Bond Strength	≥ 850 psi to OPC ≥ 1,000 psi to self Test age of 1 day for both conditions	N/A N/A	2,700 psi 2,130 psi	Pass
C469 Static Modulus of Elasticity	≤ $3x10^6$ psi test at age of 2 hr ≤ $4x10^6$ psi test at age of 3 days	N/A	$3.0 x10^6$ psi N/A	Pass
C 531 Volumetric Expansion	≤ $7 x 10^{-6}$ in/in/ºF test at age of 3 days	N/A	N/A	N/A
C 157 Volumetric Expansion	< 0.03% test begins at age of 4 days	N/A	N/A	N/A
C 1581 Shrinkage Potential	≤ 40 microstrain at 14 days and no cracking at 28 days	N/A	No Cracking	Pass
C 666 Freeze-Thaw Resistance	No requirement at this time	N/A	N/A	N/A
C 191 Time of Setting	No requirement at this time	15 min (initial) 35 min (final)	20 min (initial) 30 min (final)	N/A

Additional Product Information

Shelf life/Storage conditions

Shelf life of bagged materials is 1 year if stored in a cool dry place.

Packaging and yield

Material is packaged in 60 lb bags each yielding 0.5 cf or in 3,000 lb supersacks.

Additional material requirements

No aggregate extension required. Use citric acid as retarding agent.

Mixing method/equipment

Portable concrete mixer or rotary drum mixer. See manufacturer guide for details

Cleanup

Wash all equipment with water immediately after use.

Safety Hazards

See manufacturer MSDS for details.

Unique test conditions

[1]Not all laboratory protocol tests were conducted on this material. This material performed well in field tests for full-depth repairs.

Handling/Use Notes

Use standard concrete mixing equipment with caution due to fast set time.

Rigid Repair Material Evaluation Report

Product Name: Set 45HW		**Material Description:** Magnesium Phosphate	
Manufacturer Name and Contact Information: BASF Building Systems			
869 Valley Park Dr., Shakopee, MN 55379; 952-496-6000; http://www.buildingsystems.basf.com/			
NSN/GSA#: NSN 5610-01-564-7710			
Evaluated by: ERDC/GSL			
Date: FY06		**Result: (Pass or Fail):** Pass[1]	
Result Details			
ASTM Test	**Criteria**	**Manufacturer Test Result**	**Laboratory Test Result**	**Pass/Fail**
C 39 Compressive Strength	≥ 3,000 psi at test age of 2 hr ≥ 5,000 psi at test age of 1 day	N/A	2,820 psi 4,430 psi	Fail[2] Pass
C 78 Flexural Strength	≥ 350 psi at test age of 2 hr	650 (1 day)	N/A	N/A
C 882 Bond Strength	≥ 850 psi to OPC ≥ 1,000 psi to self Test age of 1 day for both conditions	N/A	1,240 psi 1,480 psi	Pass
C469 Static Modulus of Elasticity	≤ $3x10^6$ psi test at age of 2 hr ≤ $4x10^6$ psi test at age of 3 days	N/A 4.9 $x10^6$ (7 day)	N/A	N/A
C 531 Volumetric Expansion	≤ 7 x 10^{-6} in/in/ºF test at age of 3 days	7.15 x 10^{-6} in/in/ºF	N/A	N/A
C 157 Volumetric Expansion	< 0.03% test begins at age of 4 days	N/A	N/A	N/A
C 1581 Shrinkage Potential	≤ 40 microstrain at 14 days and no cracking at 28 days	N/A	N/A	N/A
C 666 Freeze-Thaw Resistance	No requirement at this time	80%	N/A	N/A
C 191 Time of Setting	No requirement at this time	15 min (initial) 20 min (final)	25 min (initial) 35 min (final)	N/A

Additional Product Information

Shelf life/Storage conditions

Shelf life of bagged materials is 1 year if stored in a cool dry place.

Packaging and yield

50 lb bags. Yield when extended 60% by weight aggregate is 0.58 cf.

Additional material requirements

Requires extension for repairs >2 in. depth. Extend with 60% by weight with 3/8-in. pea gravel or ½-in. noncalcareous crushed aggregate.

Mixing method/equipment

Mortar mixer or drill and paddle. See manufacturer guide for details.

Cleanup

Wash all equipment with water immediately after use.

Safety Hazards

See manufacturer MSDS for details.

Unique test conditions

[1]Not all laboratory protocol tests were conducted on this material. This material performed well in field tests for full-depth repairs. [2]UCC at 2 hr was approximately 3,000 psi.

Handling/Use Notes

Use standard concrete mixing equipment with caution due to fast set time.

Rigid Repair Material Evaluation Report

Product Name: ThoRoc 10-60	**Material Description:** Proprietary Cement
Manufacturer Name and Contact Information: BASF Building Systems	
869 Valley Park Dr., Shakopee, MN 55379; 952-496-6000; http://www.buildingsystems.basf.com/	
NSN/GSA#: NSN 5610-01-564-7710	
Evaluated by: ERDC/GSL	
Date: FY06	**Result: (Pass or Fail):** Pass[1]

Result Details

ASTM Test	Criteria	Manufacturer Test Result	Laboratory Test Result	Pass/Fail
C 39 Compressive Strength	≥ 3,000 psi at test age of 2 hr ≥ 5,000 psi at test age of 1 day	N/A 7,400 (28 day)	3,100 psi 4,360 psi	Pass
C 78 Flexural Strength	≥ 350 psi at test age of 2 hr	N/A	N/A	N/A
C 882 Bond Strength	≥ 850 psi to OPC ≥ 1,000 psi to self Test age of 1 day for both conditions	2,300 psi N/A	1,170 psi 1,850 psi	Pass
C469 Static Modulus of Elasticity	≤ $3x10^6$ psi test at age of 2 hr ≤ $4x10^6$ psi test at age of 3 days	N/A 4.4 $x10^6$ (7 day)	N/A	N/A
C 531 Volumetric Expansion	≤ 7 x 10^{-6} in/in/ºF test at age of 3 days	7 x 10^{-6} in/in/ºF	N/A	N/A
C 157 Volumetric Expansion	< 0.03% test begins at age of 4 days	N/A	N/A	N/A
C 1581 Shrinkage Potential	≤ 40 microstrain at 14 days and no cracking at 28 days	N/A	N/A	N/A
C 666 Freeze-Thaw Resistance	No requirement at this time	100%	N/A	N/A
C 191 Time of Setting	No requirement at this time	16 min (initial) 28 min (final)	20 min (initial) 25 min (final)	N/A

Additional Product Information

Shelf life/Storage conditions

Shelf life of bagged materials is 1 year if stored in a cool dry place.

Packaging and yield

50 lb bags. Yield when extended 50% by weight aggregate is 0.57 cf.

Additional material requirements

Requires extension for repairs >2 in. depth. Extend with 50% by weight with 3/8-in. pea gravel.

Mixing method/equipment

Mortar mixer or drill and paddle. See manufacturer guide for details.

Cleanup

Wash all equipment with water immediately after use.

Safety Hazards

See manufacturer MSDS for details.

Unique test conditions

[1]Not all laboratory protocol tests were conducted on this material. This material performed well in field tests for full-depth repairs.

Handling/Use Notes

Use standard concrete mixing equipment with caution due to fast set time.

Rigid Repair Material Evaluation Report

Product Name: ThoRoc 10-61	**Material Description:** Proprietary Cement
Manufacturer Name and Contact Information: BASF Building Systems	
869 Valley Park Dr., Shakopee, MN 55379; 952-496-6000; http://www.buildingsystems.basf.com/	
NSN/GSA#: NSN 5610-01-564-7710	
Evaluated by: ERDC/GSL	
Date: FY06	**Result: (Pass or Fail):** Pass[1]

Result Details

ASTM Test	Criteria	Manufacturer Test Result	Laboratory Test Result	Pass/Fail
C 39 Compressive Strength	≥ 3,000 psi at test age of 2 hr ≥ 5,000 psi at test age of 1 day	N/A 7,400 (28 day)	3,100 psi 4,360 psi	Pass
C 78 Flexural Strength	≥ 350 psi at test age of 2 hr	N/A	N/A	N/A
C 882 Bond Strength	≥ 850 psi to OPC ≥ 1,000 psi to self Test age of 1 day for both conditions	2,300 psi N/A	1,170 psi 1,850 psi	Pass
C469 Static Modulus of Elasticity	≤ $3x10^6$ psi test at age of 2 hr ≤ $4x10^6$ psi test at age of 3 days	N/A 4.4 $x10^6$ (28 day)	N/A	N/A
C 531 Volumetric Expansion	≤ 7 x 10^{-6} in/in/ºF test at age of 3 days	7 x 10^{-6} in/in/ºF	N/A	N/A
C 157 Volumetric Expansion	< 0.03% test begins at age of 4 days	N/A	N/A	N/A
C 1581 Shrinkage Potential	≤ 40 microstrain at 14 days and no cracking at 28 days	N/A	N/A	N/A
C 666 Freeze-Thaw Resistance	No requirement at this time	100%	N/A	N/A
C 191 Time of Setting	No requirement at this time	16 min (initial) 28 min (final)	20 min (initial) 25 min (final)	N/A

Additional Product Information

Shelf life/Storage conditions

Shelf life of bagged materials is 1 year if stored in a cool dry place.

Packaging and yield

50 lb bags. Yield when extended 50% by weight aggregate is 0.57 cf.

Additional material requirements

Requires extension for repairs >2 in. depth. Extend with 50% by weight with 3/8-in. pea gravel.

Mixing method/equipment

Mortar mixer or drill and paddle. See manufacturer guide for details.

Cleanup

Wash all equipment with water immediately after use.

Safety Hazards

See manufacturer MSDS for details.

Unique test conditions

[1]Not all laboratory protocol tests were conducted on this material. This material performed well in field tests for full-depth repairs.

Handling/Use Notes

Use standard concrete mixing equipment with caution due to fast set time.

Rigid Repair Material Evaluation Report

Product Name: Ultimax Concrete Mix		**Material Description:** Proprietary Cement	
Manufacturer Name and Contact Information: Ultimax Cement Corporation			
5432 Industrial Drive, Huntington Beach, CA; 714-895-7779; www.ultimaxcement.com			
NSN/GSA#: NSN 5610-01-564-7710			
Evaluated by: ERDC/GSL			
Date: FY07		**Result: (Pass or Fail):** Pass[1]	
Result Details			
ASTM Test	**Criteria**	**Manufacturer Test Result**	**Laboratory Test Result**	**Pass/Fail**
C 39 Compressive Strength	≥ 3,000 psi at test age of 2 hr ≥ 5,000 psi at test age of 1 day	N/A	4,000 psi 6,390 psi	Pass
C 78 Flexural Strength	≥ 350 psi at test age of 2 hr	N/A	385	Pass
C 882 Bond Strength	≥ 850 psi to OPC ≥ 1,000 psi to self Test age of 1 day for both conditions	N/A	1,930 psi 2,710 psi	Pass
C469 Static Modulus of Elasticity	≤ $3x10^6$ psi test at age of 2 hr ≤ $4x10^6$ psi test at age of 3 days	N/A	2.8 $x10^6$ 3.5 $x10^6$	Pass
C 531 Volumetric Expansion	≤ 7 x 10^{-6} in/in/ºF test at age of 3 days	N/A	N/A	N/A
C 157 Volumetric Expansion	< 0.03% test begins at age of 4 days	N/A	N/A	N/A
C 1581 Shrinkage Potential	≤ 40 microstrain at 14 days and no cracking at 28 days	N/A	No Cracking	Pass
C 666 Freeze-Thaw Resistance	No requirement at this time	N/A	N/A	N/A
C 191 Time of Setting	No requirement at this time	N/A	30 min (initial) 75 min (final)	N/A

Additional Product Information

Shelf life/Storage conditions

Shelf life of bagged materials is 1 year if stored in a cool dry place.

Packaging and yield

50 lb bags. Yield unknown.

Additional material requirements

Concrete mix contains aggregate extension.

Mixing method/equipment

Mortar mixer. See manufacturer guide for details.

Cleanup

Wash all equipment with water immediately after use.

Safety Hazards

See manufacturer MSDS for details.

Unique test conditions

[1]Not all laboratory protocol tests were conducted on this material. This material performed well in field tests for full-depth repairs.

Handling/Use Notes

Use standard concrete mixing equipment with caution due to fast set time.

Appendix C: ERDC FY08 Cementitious Repair Material Fact Sheets

Rigid Repair Material Evaluation Report

Product Name: ABC Cement	**Material Description:** Proprietary Cement
Manufacturer Name and Contact Information: Not commercially available at this time.	
W.D. Kirkpatrick (Kirk); 954-683-0801; wdk@abccement.com	
NSN/GSA#: NSN 5610-01-564-7710	
Evaluated by: ERDC/GSL	
Date: FY08	**Result: (Pass or Fail):** Pass

Result Details

ASTM Test	Criteria	Manufacturer Test Result	Laboratory Test Result	Pass/Fail
C 39 Compressive Strength	≥ 3,000 psi at test age of 2 hr ≥ 5,000 psi at test age of 1 day	N/A	4,580 psi 6,960 psi	Pass
C 78 Flexural Strength	≥ 350 psi at test age of 2 hr	N/A	540 psi	Pass
C 882 Bond Strength	≥ 850 psi to OPC ≥ 1,000 psi to self Test age of 1 day for both conditions	N/A N/A	850 psi 1,630 psi	Pass
C469 Static Modulus of Elasticity	≤ $3x10^6$ psi test at age of 2 hr ≤ $4x10^6$ psi test at age of 3 days	N/A	4.15×10^6 psi 5.45×10^6 psi	Fail
C 531 Volumetric Expansion	≤ 7×10^{-6} in/in/ºF test at age of 3 days	N/A	6.42×10^{-6} in/in/ºF	Pass
C 157 Volumetric Expansion	< 0.03% test begins at age of 4 days	N/A	N/A	N/A
C 1581 Shrinkage Potential	≤ 40 microstrain at 14 days and no cracking at 28 days	N/A	No Cracking	Pass
C 666 Freeze-Thaw Resistance	No requirement at this time	N/A	N/A	N/A
C 191 Time of Setting	No requirement at this time	15 min (initial) 20 min (final)	15 min (initial) 22 min (final)	N/A

Additional Product Information

Shelf life/Storage conditions

Shelf life of bagged materials is 1 year if stored in a cool dry place.

Packaging and yield

Contact manufacturer for details of liquid and dry components.

Additional material requirements

Material extended with 3/8-in. pea gravel. Liquid shipped with material.

Mixing method/equipment

Portable concrete mixer or rotary drum mixer. See manufacturer guide for details

Cleanup

Wash all equipment with water immediately after use.

Safety Hazards

See manufacturer MSDS for details.

Unique test conditions

Handling/Use Notes

Use standard concrete mixing equipment with caution due to fast set time.

Rigid Repair Material Evaluation Report

Product Name:	Pavemend SLQ	**Material Description:**	Magnesium Phosphate
Manufacturer Name and Contact Information:	Ceratech, Inc.		
1500 N. Beaurgard St. Suite 320, Alexandria, Virginia 22311; 800-341-2600; www.ceratechinc.com			
NSN/GSA#:	NSN 5610-01-564-7710		
Evaluated by:	ERDC/GSL		
Date:	FY08	**Result: (Pass or Fail):**	Pass[1]

Result Details

ASTM Test	Criteria	Manufacturer Test Result	Laboratory Test Result	Pass/Fail
C 39 Compressive Strength	≥ 3,000 psi at test age of 2 hr ≥ 5,000 psi at test age of 1 day	2,656 (1 hr) 4,524 (1 day)	1,230 psi 2,530 psi	Fail
C 78 Flexural Strength	≥ 350 psi at test age of 2 hr	600 psi (7 day) neat	305 psi	Fail
C 882 Bond Strength	≥ 850 psi to OPC ≥ 1,000 psi to self Test age of 1 day for both conditions	2,648 psi N/A	910 psi 1,240 psi	Pass
C469 Static Modulus of Elasticity	≤ $3x10^6$ psi test at age of 2 hr ≤ $4x10^6$ psi test at age of 3 days	N/A	$1.5 x10^6$ psi N/A	Pass
C 531 Volumetric Expansion	≤ $7 x 10^{-6}$ in/in/ºF test at age of 3 days	N/A	$6.32 x 10^{-6}$ in/in/ºF (7 day)	Pass
C 157 Volumetric Expansion	< 0.03% test begins at age of 4 days	0.0085% (28 days) neat	0.04% (neat) 0.016%	Fail
C 1581 Shrinkage Potential	≤ 40 microstrain at 14 days and no cracking at 28 days	N/A	No Cracking	Pass
C 666 Freeze-Thaw Resistance	No requirement at this time	99.6% (neat)	N/A	N/A
C 191 Time of Setting	No requirement at this time	3 min (initial) 6 min (final)	6 min (initial) 7.5 min (final)	N/A

Additional Product Information

Shelf life/Storage conditions

3 years in buckets.

Packaging and yield

46 lb 5 gallon buckets. Yield when extended 75% by weight aggregate is 0.72 cf.

Additional material requirements

Requires extension for full-depth repairs. Extend with 75% by weight with 3/8-in. pea gravel or ½-in. stone.

Mixing method/equipment

Drill and paddle attachment in bucket. See manufacturer guide for details.

Cleanup

Wash all equipment with water immediately after use.

Safety Hazards

See manufacturer MSDS for details.

Unique test conditions

[1]Although this material did not meet minimum requirements for rigid repair materials, it performed well as temporary repairs in recent field trials.

Handling/Use Notes

This material sets very quickly. Recent tests with this material identified expansion problems. For a temporary repair, this material performs very well. Surface finish may be difficult to achieve with this material. Because this material must be mixed in single buckets, more time is required to place multiple buckets of material than with other rapid-setting materials that can be mixed in large batches.

Rigid Repair Material Evaluation Report

Product Name: Rapid Set® Concrete Mix **Material Description:** Proprietary Cement

Manufacturer Name and Contact Information: CTS Cement Manufacturing Corporation

Mr. Chris Davis: 11065 Knott Avenue, Suite A, Cypress, CA 90630; 714-379-8270; www.ctscement.com

NSN/GSA#: NSN 5610-01-564-7710

Evaluated by: ERDC/GSL

Date: FY07 **Result: (Pass or Fail):** Pass[1]

Result Details

ASTM Test	Criteria	Manufacturer Test Result	Laboratory Test Result	Pass/Fail
C 39 Compressive Strength	≥ 3,000 psi at test age of 2 hr ≥ 5,000 psi at test age of 1 day	2,800 psi (1 hr) 5,000 psi (7 day)	5,080 psi 6,610 psi	Pass
C 78 Flexural Strength	≥ 350 psi at test age of 2 hr	420 psi	520 psi	Pass
C 882 Bond Strength	≥ 850 psi to OPC ≥ 1,000 psi to self Test age of 1 day for both conditions	N/A N/A	2,700 psi 2,130 psi	Pass
C469 Static Modulus of Elasticity	≤ $3x10^6$ psi test at age of 2 hr ≤ $4x10^6$ psi test at age of 3 days	N/A	$3.0 x10^6$ psi N/A	Pass
C 531 Volumetric Expansion	≤ $7 x 10^{-6}$ in/in/ºF test at age of 3 days	N/A	$8.27 x 10^{-6}$ in/in/ºF	Fail
C 157 Volumetric Expansion	< 0.03% test begins at age of 4 days	N/A	N/A	N/A
C 1581 Shrinkage Potential	≤ 40 microstrain at 14 days and no cracking at 28 days	N/A	No Cracking	Pass
C 666 Freeze-Thaw Resistance	No requirement at this time	N/A	N/A	N/A
C 191 Time of Setting	No requirement at this time	15 min (initial) 35 min (final)	20 min (initial) 30 min (final)	N/A

Additional Product Information

Shelf life/Storage conditions

Shelf life of bagged materials is 1 year if stored in a cool dry place.

Packaging and yield

Material is packaged in 60 lb bags each yielding 0.5 cf or in 3,000 lb supersacks.

Additional material requirements

No aggregate extension required. Use citric acid as retarding agent.

Mixing method/equipment

Portable concrete mixer or rotary drum mixer. See manufacturer guide for details

Cleanup

Wash all equipment with water immediately after use.

Safety Hazards

See manufacturer MSDS for details.

Unique test conditions

[1]Not all laboratory protocol tests were conducted on this material. This material performed well in field tests for full-depth repairs.

Handling/Use Notes

Use standard concrete mixing equipment with caution due to fast set time.

Appendix D: ERDC FY09 Cementitious Repair Material Fact Sheets

Rigid Repair Material Evaluation Report

Product Name: DOTLine	**Material Description:** Rapid Repair Concrete
Manufacturer Name and Contact Information: CERATECH Incorporated	
1500 North Beaurgard St. Suite 320, Alexandria, VA 22311	
NSN/GSA#:	
Evaluated by: Burns Cooley Dennis, Inc	
Date: June 2009	**Result: (Pass or Fail):** Fail-shrinkage

Result Details

ASTM Test	Criteria	Manufacturer Test Result	Laboratory Test Result	Pass/Fail
C 39 Compressive Strength	≥ 3,000 psi at test age of 2 hr ≥ 5,000 psi at test age of 1 day	2,820 psi @ 2hrs 6,115 psi @ 1day	3,287 psi @ 2 hrs 6,280 psi @ 1day	Pass–2 hr Pass–1 day
C 78 Flexural Strength	≥ 350 psi at test age of 2 hrs and 1 day	690 psi @ 1 day	385 psi @ 2 hrs 595 psi @ 1 day	Pass-2 hr Pass-1 day
C 882 Bond Strength	≥ 850 psi to OPC mortar ≥ 1,000 psi to self Test age of 1 day for both conditions	1,960 psi @ 1 day. Does not specify OPC mortar or itself.	1,657 psi @ 1day OPC mortar.	Pass
C469 Modulus of Elasticity	≤ $3x10^6$ psi test at age of 2 hr ≤ $4x10^6$ psi test at age of 3 days	$5.2x10^6$ psi @ 28 days.	$3.05x10^6$ @ 2hrs $4.20x10^6$ @ 3day	Pass-2 hrs Fail-3 day
C 531 Volumetric Expansion	≤ 7 x 10^{-6} in/in/°F test begins at age of 3 days	1.32 in/in/°F @ 28 days.	$2.65x10^{-6}$ in/in/°F	Pass
C 157 Volumetric Expansion	<+0.03% Expansion or <-0.04% Shrinkage @ 28 Days	-0.052	-0.0583% @ 28 days	Fail
C 1581 Shrinkage Potential	≤ 40 microstrain at 14 days and no cracking at 28 days	NA	All specimens cracked before 14 days	Fail-strain Fail-crack
C 666 Freeze-Thaw Resistance	No requirement at this time	NA	Not Tested	Not Tested
C 191 Time of Setting	No requirement at this time	NA	17 minutes	NA

Additional Product Information

Shelf life/Storage conditions

1 year

Packaging and yield

0.40 cubic foot per bag. 53.5 lb per bag.

Additional material requirements

None

Mixing method/equipment

Approximately 70% of mix water was put in mix, mixer was started and all contents of the bag(s) were added. Total mixing time was 7 minutes. Minimum recommend batch size is two units.

Cleanup

Clean all tools with water prior to final set.

Safety Hazards

See Material Safety Data Sheets.

Unique test conditions

Specimens were cured for approximately 1 hour in laboratory conditions and final curing was ±73 °F and ±50% humidity.

Handling/Use Notes

None.

Rigid Repair Material Evaluation Report

Product Name: Main Line	**Material Description:** Rapid Repair Concrete
Manufacturer Name and Contact Information: CERATECH Incorporated	
1500 North Beaurgard St. Suite 320, Alexandria, VA 22311	
NSN/GSA#:	
Evaluated by: Burns Cooley Dennis, Inc	
Date: June 2009	**Result: (Pass or Fail):** Fail-shrinkage/strength

Result Details

ASTM Test	Criteria	Manufacturer Test Result	Laboratory Test Result	Pass/Fail
C 39 Compressive Strength	≥ 3,000 psi at test age of 2 hr ≥ 5,000 psi at test age of 1 day	3,010 psi @ 4 hr 4,905 psi @ 1day	2,223 psi @ 2 hrs 5,074 psi @ 1day	Fail–2 hr Pass–1 day
C 78 Flexural Strength	≥ 350 psi at test age of 2 hrs and 1 day	490 psi @ 1 day	320 psi @ 2 hrs 430 psi @ 1 day	Fail-2 hr Pass-1 day
C 882 Bond Strength	≥ 850 psi to OPC mortar ≥ 1,000 psi to self Test age of 1 day for both conditions	2,503 psi @ 1 day. Does not specify OPC mortar or itself.	1,672 psi @ 1 day OPC mortar.	Pass
C469 Modulus of Elasticity	≤ $3x10^6$ psi test at age of 2 hr ≤ $4x10^6$ psi test at age of 3 days	$4.7x10^6$ psi @ 28 days.	$2.35x10^6$ @ 2hrs $3.85x10^6$ @ 3day	Pass-2 hrs Pass-3 day
C 531 Volumetric Expansion	≤ 7 x 10^{-6} in/in/°F test begins at age of 3 days	1.37 in/in/°F @ 28 days.	$3.24x10^{-6}$ in/in/°F	Pass
C 157 Volumetric Expansion/Shrinkage	<+0.03% Expansion or <-0.04% Shrinkage @ 28 Days	-0.052% @ 28 days	-0.0313 % @ 28 days	Pass
C 1581 Shrinkage Potential	≤ 40 microstrain at 14 days and no cracking at 28 days	NA	51 microstrain Specimen 1 cracked at 8 days	Fail-strain Fail-crack
C 666 Freeze-Thaw Resistance	No requirement at this time	NA	Not Tested	Not Tested
C 191 Time of Setting	No requirement at this time	NA	22 minutes	NA

Additional Product Information

Shelf life/Storage conditions

1 year

Packaging and yield

0.40 cubic foot per bag. 53 lb per bag.

Additional material requirements

None

Mixing method/equipment

Approximately 70% of mix water was put in mix, mixer was started and all contents of the bag(s) were added. Total mixing time was 7 minutes. Minimum recommend batch size is two untis.

Cleanup

Clean all tools with water prior to final set.

Safety Hazards

See Material Safety Data Sheets.

Unique test conditions

Specimens were cured for approximately 1 hour at laboratory conditions. Final curing was ±73° F and ±50% humidity.

Handling/Use Notes

None.

Rigid Repair Material Evaluation Report

Product	Great White	**Material Description:**	Rapid Repair Concrete
Manufacturer Name and Contact Information:	CERATECH Incorporated		
1500 North Beaurgard St. Suite 320, Alexandria, VA 22311			
NSN/GSA#:			
Evaluated by:	Burns Cooley Dennis, Inc		
Date:	July 2009	**Result: (Pass or Fail):**	

Result Details

ASTM Test	Criteria	Manufacturer Test Result	Laboratory Test Result	Pass/Fail
C 39 Compressive Strength	≥ 3,000 psi at test age of 2 hr ≥ 5,000 psi at test age of 1 day	2,800 psi @ 2hr 4,550 psi @ 1day	2,340 psi @ 2 hr 4,195 psi @ 1day	Fail–2 hr Fail–1 day
C 78 Flexural Strength	≥ 350 psi at test age of 2 hrs and 1 day	>350 psi @ 1 day	355 psi @ 2 hr 525 psi @ 1 day	Pass-2 hr Pass-1 day
C 882 Bond Strength	≥ 850 psi to OPC mortar ≥ 1,000 psi to self Test age of 1 day for both conditions		891 psi @ 1day OPC mortar.	Pass
C469 Modulus of Elasticity	≤ $3x10^6$ psi test at age of 2 hr ≤ $4x10^6$ psi test at age of 3 days	$5.4x10^6$ psi @ 28 days.	$3.60x10^6$ @ 2hr $4.50x10^6$ @ 3day	Fail-2 hr Fail-3 day
C 531 Volumetric Expansion	≤ 7×10^{-6} in/in/°F test begins at age of 3 days	$4.7x10^{-6}$ in/in/°F @ 28 days.	$4.61x10^{-6}$ in/in/°F	Pass
C 157 Volumetric Expansion	<+0.03% Expansion or <-0.04% Shrinkage @ 28 Days	NA	-0.0203% at 28 days	Pass
C 1581 Shrinkage Potential	≤ 40 microstrain at 14 days and no cracking at 28 days	NA	< 40 microstrain at 14 days No cracking	Pass-Strain Pass-Crack
C 666 Freeze-Thaw Resistance	No requirement at this time	NA	Not Tested	Not Tested
C 191 Time of Setting	No requirement at this time	NA	35 minutes	NA

Additional Product Information

Shelf life/Storage conditions

1 year

Packaging and yield

75 pound bag - 2.5 cubic foot; 2,200 pound bag - 3.0 cubic yards

Additional material requirements

Fine and Coarse Aggregate. Requires mix design.

Mixing method/equipment

Added aggregates and mixed for approximately 1 minute. Added cement and mixed for approximately 1 minute. Added water, activator, and eclipse floor simultaneously and mixed for 4 minutes and 30 seconds. See concrete mixture design for mix proportions.

Cleanup

Clean all tools with water prior to final set.

Safety Hazards

See Material Safety Data Sheets.

Unique test conditions

Specimens were cured for approximately 2 hours in laboratory conditions and final curing was ±73°F and ±50% humidity.

Handling/Use Notes

Great White has a two component activator. Proper proportioning of the activator is critical in controlling slump and set time. The coarse aggregate used in the Great White mixes was No. 57 limestone. The mix was sieved over a No. 4 sieve for determining set time and a 1/2 inch sieve for volumetric expansion (C 531). **Although this material did not meet all test requirements, field tests of the material withstood > 2,000 passes of C-17 load cart traffic without failing.

Rigid Repair Material Evaluation Report

Product Name: Pavemend TR		**Material Description:** Magnesium Phosphate	
Manufacturer Name and Contact Information: Ceratech, Inc.			
1500 N. Beaurgard St. Suite 320, Alexandria, Virginia 22311; 800-341-2600; www.ceratechinc.com			
NSN/GSA#: NSN 5610-01-564-7710			
Evaluated by: ERDC/GSL			
Date: FY08		**Result: (Pass or Fail):** **Pass**[1]	
Result Details			
ASTM Test	**Criteria**	**Manufacturer Test Result**	**Laboratory Test Result**	**Pass/Fail**
C 39 Compressive Strength	≥ 3,000 psi at test age of 2 hr ≥ 5,000 psi at test age of 1 day	3,104 psi (3 hr) 5,352 psi (1 day)	260 psi 3,930 psi	Fail
C 78 Flexural Strength	≥ 350 psi at test age of 2 hr	620 psi (2 day) neat	75 psi	Fail
C 882 Bond Strength	≥ 850 psi to OPC ≥ 1,000 psi to self Test age of 1 day for both conditions	1,270 psi (neat) N/A	1,430 psi 1,700 psi	Pass
C469 Static Modulus of Elasticity	≤ $3x10^6$ psi test at age of 2 hr ≤ $4x10^6$ psi test at age of 3 days	$2.77 x10^6$ psi (28 day) neat N/A	$0.55 x10^6$ psi N/A	Pass
C 531 Volumetric Expansion	≤ 7×10^{-6} in/in/°F test at age of 3 days	2.52×10^{-6} in/in/°F (28 day)	6.30×10^{-6} in/in/°F (7 day)	N/A
C 157 Volumetric Expansion	< 0.03% test begins at age of 4 days	-0.002% (neat)	N/A	N/A
C 1581 Shrinkage Potential	≤ 40 microstrain at 14 days and no cracking at 28 days	N/A	No Cracking	Pass
C 666 Freeze-Thaw Resistance	No requirement at this time	100%	N/A	N/A
C 191 Time of Setting	No requirement at this time	10 min (initial) 25 min (final)	18 min (initial) 26 min (final)	N/A

Additional Product Information

Shelf life/Storage conditions

3 years in buckets.

Packaging and yield

47 lb 5 gallon buckets. Yield when extended 75% by weight aggregate is 0.71 cf.

Additional material requirements

Requires extension for full-depth repairs. Extend with 75% by weight with 3/8-in. pea gravel or ½-in. stone.

Mixing method/equipment

Drill and paddle attachment in bucket. Or in portable concrete mixer. See manufacturer guide for details.

Cleanup

Wash all equipment with water immediately after use. If using drum mixer, wash between batches.

Safety Hazards

See manufacturer MSDS for details.

Unique test conditions

[1]Not all laboratory protocol tests were conducted on this material. Although this material did not meet minimum requirements for rigid repair materials, it performed well in full-depth repairs in recent field trials If the repair was allowed to cure for a minimum of 4 hr.

Handling/Use Notes

Surface finish may be difficult to achieve with this material. Use standard concrete mixing equipment with caution due to fast set time. Material required 4 hours of cure prior to the application of aircraft traffic.

Appendix E: ERDC FY10 Cementitious Repair Material Fact Sheets

Rigid Repair Material Evaluation Report

Product Name:	Rapid Set Concrete Mix 73°F	**Material Description:**	Rapid Repair Concrete
Manufacturer Name and Contact Information:	CTS Cement		
NSN/GSA#:			
Evaluated by:	Burns Cooley Dennis, Inc		
Date:	April 12-16, 2010	**Result: (Pass or Fail):**	Pass

Result Details

ASTM Test	Criteria	Manufacturer Test Result	Laboratory Test Result	Pass/Fail
C 39 Compressive Strength	≥ 3,000 psi at test age of 2 hr ≥ 5,000 psi at test age of 1 day	Not reported	3,404 psi @ 2hr 4,512 psi @ 1day	Pass –2 hr Fail–1 day
C 78 Flexural Strength	≥ 350 psi at test age of 2 hr and 1 day	420 psi @ 2 hr 650 psi @ 1 day	390 psi @ 2 hr 580 psi @ 1 day	Pass - 2 hr Pass -1 day
C 882 Bond Strength	≥ 850 psi to OPC mortar ≥ 1,000 psi to self Test age of 1 day for both conditions	Not reported	850 psi @ 1day OPC mortar.	Pass
C469 Modulus of Elasticity	≤ $3x10^6$ psi test at age of 2 hr ≤ $4x10^6$ psi test at age of 3 days	Not reported	$3.15x10^6$ @ 2hr $3.65x10^6$ @ 3day	Fail-2 hr Pass-3 day
C 531 Volumetric Expansion	≤ 7 x 10^{-6} in/in/°F test begins at age of 3 days	Not reported	3.43 $x10^6$	Pass
C 157 Volumetric Expansion	<+0.03% Expansion or <-0.04% Shrinkage @ 28 Days	Not reported	+0.01%@ 28days -0.00%@28days	Pass-Exp. Pass-Shr.
C 1581 Shrinkage Potential	≤ 40 microstrain at 14 days and no cracking at 28 days	Not reported	No cracks.	Pass
C 666 Freeze-Thaw Resistance	No requirement at this time	No sign of spalling@ 300 cycles. Average weight loss of 0.4%.	Not Tested	Not Tested
C 191 Time of Setting	No requirement at this time	Initial- 15minutes Final–35 minutes	Set - 18 minutes Final–22minutes	NA

Additional Product Information

Shelf life/Storage conditions

None reported.

Packaging and yield

Material is packaged in 60 pound bags. Yield is not reported.

Additional material requirements

Water added at 3 to 5 quarts of water per 60 pounds of material. 4 quarts of water per 60 pounds of Rapid Set Concrete was used for laboratory testing.

Mixing method/equipment

Mixed with a laboratory drum mixer. All water was added up front into a pre-wetted mixer. One bag of material was added at a time and was mixed with a few revolutions of the drum. After all materials were added, this material was mixed for 1 to 2 minutes until uniform.

Cleanup

Clean tools as soon as possible with water.

Safety Hazards

See Material Safety Data Sheets.

Unique test conditions

Specimens were cured for approximately 1 hour in laboratory conditions and final curing was ±73°F and ±50% humidity unless noted. Specimens for testing C 157 were cured for approximately 1 hour in laboratory conditions, placed in a moisture room for approximately 24 hours, cured in a water bath at ±73°F for 27 days, and final curing was at ±73 F and ±50% humidity for 28 days.

Handling/Use Notes

Mix was very workable.

Rigid Repair Material Evaluation Report

Product Name:	HD-50 73°F	**Material Description:**	Rapid Repair Concrete
Manufacturer Name and Contact Information:	Dayton Superior		
NSN/GSA#:			
Evaluated by:	Burns Cooley Dennis, Inc		
Date:	March 26-29, 2010	**Result: (Pass or Fail):**	Pass

Result Details

ASTM Test	Criteria	Manufacturer Test Result	Laboratory Test Result	Pass/Fail
C 39 Compressive Strength	≥ 3,000 psi at test age of 2 hr ≥ 5,000 psi at test age of 1 day	Not reported @ 2 hr 6,145psi @ 1day	3,111 psi @ 2hr 4,793 psi @ 1day	Pass–2 hr Fail–1 day
C 78 Flexural Strength	≥ 350 psi at test age of 2 hrs and 1 day	Not reported	360 psi @ 2 hr 555 psi @ 1 day	Pass-2 hr Pass-1 day
C 882 Bond Strength	≥ 850 psi to OPC mortar ≥ 1,000 psi to self Test age of 1 day for both conditions	1,950psi@1 day	2,568 psi @ 1day OPC mortar.	Pass
C469 Modulus of Elasticity	≤ $3x10^6$ psi test at age of 2 hr ≤ $4x10^6$ psi test at age of 3 days	Not reported	$3.55x10^6$ @ 2hr $4.10x10^6$ @ 3day	Fail-2 hr Fail-3 day
C 531 Volumetric Expansion	≤ 7 x 10^{-6} in/in/°F test begins at age of 3 days	Not reported	$5.4x10^{-6}$ in/in/°F	Pass
C 157 Volumetric Expansion	<+0.03% Expansion or <-0.04% Shrinkage @ 28 Days	Not reported	+0.02% @28days -0.01%@28days	Pass –Exp. Pass - Shr.
C 1581 Shrinkage Potential	≤ 40 microstrain at 14 days and no cracking at 28 days	Not reported	No cracking	Pass
C 666 Freeze-Thaw Resistance	No requirement at this time	No loss @ 300 cycles	Not Tested	Not Tested
C 191 Time of Setting	No requirement at this time	Not reported	Set - 22 minutes Final–26 minutes	NA

Additional Product Information

Shelf life/Storage conditions

Not reported.

Packaging and yield

Material is packaged in 50 lb bags and yields 0.43 ft^3 per bag when mixed with the recommend water. Yield is 0.60 with 60% extension (30 lbs) of 3/8" pea gravel.

Additional material requirements

Water added at 13.5% by weight of HD-50. Saturated surface dry pear gravel is added at a rate of 60% by weight of HD-50.

Mixing method/equipment

HD-50 was mixed with a laboratory drum mixer. Most water was added up front into a pre-wetted mixer. Pea gravel was added along with remaining water added to wash down mixer. HD-50 was mixed for 2 to 3 minutes until it appeared uniform.

Cleanup

Clean tools as soon as possible with water.

Safety Hazards

See Material Safety Data Sheets.

Unique test conditions

Specimens were cured for approximately 1 hour in laboratory conditions and final curing was ±73°F and ±50% humidity unless noted. Specimens for testing C 157 were cured approximately 1 hour in laboratory conditions, placed in a moisture room for approximately 24 hours, cured in a water bath at ±73°F for 27 days, and final curing was at ±73°F and ±50% humidity for 28 days.

Handling/Use Notes

Mix was very workable.

Rigid Repair Material Evaluation Report

Product Name:	FasTrac at 73° F	**Material Description:**	Rapid Repair Concrete
Manufacturer Name and Contact Information:	Western Material & Design, LLC		
NSN/GSA#:			
Evaluated by:	Burns Cooley Dennis, Inc		
Date:	March 16-22, 2010	**Result: (Pass or Fail):**	Fail

Result Details

ASTM Test	Criteria	Manufacturer Test Result	Laboratory Test Result	Pass/Fail
C 39 Compressive Strength	≥ 3,000 psi at test age of 2 hr ≥ 5,000 psi at test age of 1 day	2,000 psi @ 2hr 5,000 psi @ 1day	4,370 psi @ 2hr 5,862 psi @ 1day	Pass–2 hr Pass–1 day
C 78 Flexural Strength	≥ 350 psi at test age of 2 hr and 1 day	Not reported	475 psi @ 2 hr 650 psi @ 1 day	Pass-2 hr Pass-1 day
C 882 Bond Strength	≥ 850 psi to OPC mortar ≥ 1,000 psi to self Test age of 1 day for both conditions	Not reported	3,160 psi @ 1day OPC mortar.	Pass
C469 Modulus of Elasticity	≤ $3x10^6$ psi test at age of 2 hr ≤ $4x10^6$ psi test at age of 3 days	Not reported	$4.00x10^6$ @ 2hr $4.5x10^6$ @ 3day	Fail-2 hr Fail-3 day
C 531 Volumetric Expansion	≤ 7 x 10^{-6} in/in/°F test begins at age of 3 days	Not reported	$3.47x10^{-6}$ in/in/°F	Pass
C 157 Volumetric Expansion	<+0.03% Expansion or <-0.04% Shrinkage @ 28 Days	Not reported	+0.04% @28 day -0.004% @28day	Fail – Exp. Pass-Shr.
C 1581 Shrinkage Potential	≤ 40 microstrain at 14 days and no cracking at 28 days	Not reported	Erratic Data	Fail
C 666 Freeze-Thaw Resistance	No requirement at this time	Not reported	Not Tested	Not Tested
C 191 Time of Setting	No requirement at this time	Initial 40-50 Final 45-60	Set - 15 minutes Final–22 minutes	NA

Additional Product Information

Shelf life/Storage conditions

Shelf life is 1 year when properly stored. Store and transport in clean, dry conditions at 40°F to 85°F in unopened containers. Application temperature range from 40°F to 90°F.

Packaging and yield

Material is packaged in 60 lb bags and yields 0.45 ft^3 per bag when mixed with the recommend water.

Additional material requirements

Water added at 8% by weight of FasTrac.

Mixing method/equipment

FasTrac was mixed with a laboratory drum mixer. Most water was added up front into a pre-wetted mixer. FasTrac was then added with the remaining water added to wash down mixer. FasTrac was mixed for 2 or 3 minutes until it appeared uniform

Cleanup

Clean tools as soon as possible with water.

Safety Hazards

See Material Safety Data Sheets.

Unique test conditions

Specimens were cured for approximately 1 hour in laboratory conditions and final curing was ±73°F and ±50% humidity unless noted. Specimens for testing C 157 were cured for approximately 1 hour in laboratory conditions, placed in a moisture room for approximately 24 hours, cured in a water bath at ±73°F for 27 days, and final curing was at ±73°F and ±50% humidity for 28 days.

Handling/Use Notes

Mix was too stiff using 8% water by weight of FasTrac and we had difficulty consolidating specimens.

Rigid Repair Material Evaluation Report

Product Name:	FasTrac w/ Citric Acid at 73º F	**Material Description:**	Rapid Repair Concrete
Manufacturer Name and Contact Information:	Western Material & Design, LLC		
NSN/GSA#:			
Evaluated by:	Burns Cooley Dennis, Inc		
Date:	May 7-11, 2010	**Result: (Pass or Fail):**	Fail

Result Details

ASTM Test	Criteria	Manufacturer Test Result	Laboratory Test Result	Pass/Fail
C 39 Compressive Strength	≥ 3,000 psi at test age of 2 hr ≥ 5,000 psi at test age of 1 day	2,000 psi @ 2hr 5,000 psi @ 1day	1,117 psi @ 2hr 4,364 psi @ 1day	Fail - 2 hr Fail–1 day
C 78 Flexural Strength	≥ 350 psi at test age of 2 hr and 1 day	Not reported	385 psi @ 2 hr 525 psi @ 1 day	Pass-2 hr Pass-1 day
C 882 Bond Strength	≥ 850 psi to OPC mortar ≥ 1,000 psi to self Test age of 1 day for both conditions	Not reported	2,737 psi @ 1day OPC mortar.	Pass
C469 Modulus of Elasticity	≤ $3x10^6$ psi test at age of 2 hr ≤ $4x10^6$ psi test at age of 3 days	Not reported	$3.50x10^6$ @ 2hr $2.15x10^6$ @ 3day	Fail-2 hr Pass-3 day
C 531 Volumetric Expansion	≤ 7×10^{-6} in/in/ºF test begins at age of 3 days	Not reported	$2.5x10^{-6}$ in/in/ºF	Pass
C 157 Volumetric Expansion	<+0.03% Expansion or <-0.04% Shrinkage @ 28 Days	Not reported	+0.04% @28days	Fail
C 1581 Shrinkage Potential	≤ 40 microstrain at 14 days and no cracking at 28 days	Not reported	31 microstrain at 14 days. No visible cracking.	Pass-strain Pass-crack
C 666 Freeze-Thaw Resistance	No requirement at this time	Not reported	Not Tested	Not Tested
C 191 Time of Setting	No requirement at this time	Initial 40-50 Final 45-60	Set - 44 minutes Final–50 minutes	NA

Additional Product Information

Shelf life/Storage conditions

Shelf life is 1 year when properly stored. Store and transport in clean, dry conditions at 40°F to 85°F in unopened containers. Application temperature range from 40°F to 90°F.

Packaging and yield

Material is packaged in 60 lb bags and yields 0.45 ft^3 per bag when mixed with the recommend water.

Additional material requirements

Water added at 4.76 lb per 60 pounds of FasTrac. Citric acid was added to the mix water at 0.04 pounds per 60 pounds of FasTrac.

Mixing method/equipment

FasTrac was mixed with a laboratory drum mixer. Most water was added up front into a pre-wetted mixer. FasTrac was then added with the remaining water added to wash down mixer. FasTrac was mixed for 2 or 3 minutes until it appeared uniform

Cleanup

Clean tools as soon as possible with water.

Safety Hazards

See Material Safety Data Sheets.

Unique test conditions

Specimens were cured for approximately 1 hour in laboratory conditions and final curing was ±73°F and ±50% humidity unless noted. Specimens for testing C 157 were cured for approximately 1 hour in laboratory conditions, placed in a moisture room for approximately 24 hours, cured in a water bath at ±73°F for 27 days, and final curing was at ±73°F and ±50% humidity for 28 days.

Handling/Use Notes

Mix was very workable.

Rigid Repair Material Evaluation Report

Product Name:	Premium Patch 200 73°F	**Material Description:**	Rapid Repair Concrete
Manufacturer Name and Contact Information:	PROSPEC		
NSN/GSA#:			
Evaluated by:	Burns Cooley Dennis, Inc		
Date:	April 1-6, 2010	**Result: (Pass or Fail):**	Pass

Result Details

ASTM Test	Criteria	Manufacturer Test Result	Laboratory Test Result	Pass/Fail
C 39 Compressive Strength	≥ 3,000 psi at test age of 2 hr ≥ 5,000 psi at test age of 1 day	Not reported	3,268 psi @ 2hr 4,515 psi @ 1day	Pass–2 hr Fail–1 day
C 78 Flexural Strength	≥ 350 psi at test age of 2 hr and 1 day	Not reported	420 psi @ 2 hr 505 psi @ 1 day	Pass-2 hr Pass-1 day
C 882 Bond Strength	≥ 850 psi to OPC mortar ≥ 1,000 psi to self Test age of 1 day for both conditions	1,500 psi@1 day	2,314 psi @ 1day OPC mortar.	Pass
C469 Modulus of Elasticity	≤ $3x10^6$ psi test at age of 2 hr ≤ $4x10^6$ psi test at age of 3 days	Not reported	$3.70x10^6$ @ 2hr $4.65x10^6$ @ 3day	Fail-2 hr Fail-3 day
C 531 Volumetric Expansion	≤ 7×10^{-6} in/in/°F test begins at age of 3 days	Not reported	$5.6x10^{-6}$ in/in/°F	Pass
C 157 Volumetric Expansion	<+0.03% Expansion or <-0.04% Shrinkage @ 28 Days	Not reported	0.02% @ 28 days -0.00% @ 28 days	Pass –Exp. Pass – Shr.
C 1581 Shrinkage Potential	≤ 40 microstrain at 14 days and no cracking at 28 days	Not reported	No cracking	Pass
C 666 Freeze-Thaw Resistance	No requirement at this time	No sign of spalling@ 300 cycles. Average weight loss of 0.4%.	Not Tested	Not Tested
C 191 Time of Setting	No requirement at this time	Initial- 18minutes Final–20 minutes	Set - 26 minutes Final–31minutes	NA

Additional Product Information

Shelf life/Storage conditions

Shelf life is one year when stored properly in original unopened container. Keep in cool/dry place unexposed to sunlight tightly sealed container.

Packaging and yield

Material is packaged in 50 pound bags and yields 0.43 ft^3 per bag when mixed with the recommend water. Yield is 0.61 with 60% extension (30 lb) of 3/8" pea gravel.

Additional material requirements

Water added at 3.25 quarts of water per 50 pounds of Premium 200. Saturated surface dry pea gravel is added at a rate of 60% by weight of Premium 200.

Mixing method/equipment

Premium 200 was mixed with a laboratory drum mixer. All water was added up front into a pre-wetted mixer. ½ of Premium 200 was added to the water and mixed. Second half of Premium 200 was added and mixed. Pea gravel was added and mixed for 2 to 3 minutes until it appeared uniform.

Cleanup

Clean tools as soon as possible with water.

Safety Hazards

See Material Safety Data Sheets.

Unique test conditions

Specimens were cured for approximately 1 hour in laboratory conditions and final curing was ±73°F and ±50% humidity unless noted. Specimens for testing C 157 were cured for approximately 1 hour in laboratory conditions, placed in a moisture room for approximately 24 hours, cured in a water bath at ±73°F for 27 days, and final curing was at ±73°F and ±50% humidity for 28 days.

Handling/Use Notes

Mix was very workable.

Appendix F: MST FY10 Cementitious Repair Material Fact Sheets

Rigid Repair Material Evaluation Report

Product Name: ABC Cement		**Material Description:** Rapid Repair Concrete	
Manufacturer Name and Contact Information: ABC Cement			
NSN/GSA#:			
Evaluated by: Missouri S&T (MST)			
Date: 2010	**Result: (Pass or Fail):** Fail		
Result Details			
ASTM Test	**Criteria**	**Manufacturer Test Result**	**Laboratory Test Result**	**Pass/Fail**
C 39 Compressive Strength	≥ 3,000 psi at test age of 2 hr ≥ 5,000 psi at test age of 1 day	Not reported	2,630 psi @ 2hr	Fail –2 hr
C 78 Flexural Strength	≥ 350 psi at test age of 2 hr and 1 day	Not reported	412 psi @ 2 hr	Pass - 2 hr
C 882 Bond Strength	≥ 850 psi to OPC mortar ≥ 1,000 psi to self Test age of 1 day for both conditions	Not reported	Not Tested	Not Tested
C469 Modulus of Elasticity	≤ $3x10^6$ psi test at age of 2 hr ≤ $4x10^6$ psi test at age of 3 days	Not reported	$3.00x10^6$ @ 2hr	Pass-2 hr
C 531 Volumetric Expansion	≤ 7×10^{-6} in/in/°F test begins at age of 3 days	Not reported	Not Tested	Not Tested
C 157 Volumetric Expansion	<+0.03% Expansion or <-0.04% Shrinkage @ 28 Days	Not reported	Not Tested	Not Tested
C 1581 Shrinkage Potential	≤ 40 microstrain at 14 days and no cracking at 28 days	Not reported	Not Tested	Not Tested
C 666 Freeze-Thaw Resistance	No requirement at this time	Not reported	Not Tested	Not Tested
C 191 Time of Setting	No requirement at this time	Not reported	Set – 34.5 minutes Final–38.5 minutes	NA

Additional Product Information

Shelf life/Storage conditions

None reported.

Packaging and yield

None reported.

Additional material requirements

None reported.

Mixing method/equipment

None reported.

Cleanup

Clean tools as soon as possible with water.

Safety Hazards

See Material Safety Data Sheets.

Unique test conditions

None reported.

Handling/Use Notes

None reported.

Rigid Repair Material Evaluation Report

Product Name:	HD-50	**Material Description:**	Rapid Repair Concrete
Manufacturer Name and Contact Information:	None reported		
NSN/GSA#:			
Evaluated by:	Missouri S&T (MST)		
Date:	2010	**Result: (Pass or Fail):**	Fail

Result Details

ASTM Test	Criteria	Manufacturer Test Result	Laboratory Test Result	Pass/Fail
C 39 Compressive Strength	≥ 3,000 psi at test age of 2 hr ≥ 5,000 psi at test age of 1 day	Not reported	2,810 psi @ 2hr	Fail –2 hr
C 78 Flexural Strength	≥ 350 psi at test age of 2 hrs and 1 day	Not reported	379 psi @ 2 hr	Pass - 2 hr
C 882 Bond Strength	≥ 850 psi to OPC mortar ≥ 1,000 psi to self Test age of 1 day for both conditions	Not reported	Not Tested	Not Tested
C469 Modulus of Elasticity	≤ $3x10^6$ psi test at age of 2 hr ≤ $4x10^6$ psi test at age of 3 days	Not reported	$2.70x10^6$ @ 2hr	Pass-2 hr
C 531 Volumetric Expansion	≤ 7×10^{-6} in/in/°F test begins at age of 3 days	Not reported	Not Tested	Not Tested
C 157 Volumetric Expansion	<+0.03% Expansion or <-0.04% Shrinkage @ 28 Days	Not reported	Not Tested	Not Tested
C 1581 Shrinkage Potential	≤ 40 microstrain at 14 days and no cracking at 28 days	Not reported	No cracks.	Pass
C 666 Freeze-Thaw Resistance	No requirement at this time	Not reported	Not Tested	Not Tested
C 191 Time of Setting	No requirement at this time	Not reported	Set – 31.5 minutes Final–35 minutes	NA

Additional Product Information

Shelf life/Storage conditions

None reported.

Packaging and yield

None reported.

Additional material requirements

None reported.

Mixing method/equipment

None reported.

Cleanup

Clean tools as soon as possible with water.

Safety Hazards

See Material Safety Data Sheets.

Unique test conditions

None reported.

Handling/Use Notes

None reported.

Rigid Repair Material Evaluation Report

Product Name:	Pavepatch 3000	**Material Description:**	Rapid Repair Concrete
Manufacturer Name and Contact Information:	None reported		
NSN/GSA#:			
Evaluated by:	Missouri S&T (MST)		
Date:	2010	**Result: (Pass or Fail):**	Fail

Result Details

ASTM Test	Criteria	Manufacturer Test Result	Laboratory Test Result	Pass/Fail
C 39 Compressive Strength	≥ 3,000 psi at test age of 2 hr ≥ 5,000 psi at test age of 1 day	Not reported	2,850 psi @ 2hr	Fail –2 hr
C 78 Flexural Strength	≥ 350 psi at test age of 2 hr and 1 day	Not reported	389 psi @ 2 hr	Pass - 2 hr
C 882 Bond Strength	≥ 850 psi to OPC mortar ≥ 1,000 psi to self Test age of 1 day for both conditions	Not reported	Not Tested	Not Tested
C469 Modulus of Elasticity	≤ $3x10^6$ psi test at age of 2 hr ≤ $4x10^6$ psi test at age of 3 days	Not reported	$2.90x10^6$ @ 2hr	Pass-2 hr
C 531 Volumetric Expansion	≤ 7×10^{-6} in/in/°F test begins at age of 3 days	Not reported	Not Tested	Not Tested
C 157 Volumetric Expansion	<+0.03% Expansion or <-0.04% Shrinkage @ 28 Days	Not reported	Not Tested	Not Tested
C 1581 Shrinkage Potential	≤ 40 microstrain at 14 days and no cracking at 28 days	Not reported	Not Tested	Not Tested
C 666 Freeze-Thaw Resistance	No requirement at this time	Not reported	Not Tested	Not Tested
C 191 Time of Setting	No requirement at this time	Not reported	Set – 33.5 minutes Final–41 minutes	NA

Additional Product Information

Shelf life/Storage conditions

None reported.

Packaging and yield

None reported.

Additional material requirements

None reported.

Mixing method/equipment

None reported.

Cleanup

Clean tools as soon as possible with water.

Safety Hazards

See Material Safety Data Sheets.

Unique test conditions

None reported.

Handling/Use Notes

None reported.

Rigid Repair Material Evaluation Report

Product Name:	Quikcrete Fast Set DOT Mix	**Material Description:**	Rapid Repair Concrete
Manufacturer Name and Contact Information:	None reported		
NSN/GSA#:			
Evaluated by:	Missouri S&T (MST)		
Date:	2010	**Result: (Pass or Fail):**	Pass

Result Details

ASTM Test	Criteria	Manufacturer Test Result	Laboratory Test Result	Pass/Fail
C 39 Compressive Strength	≥ 3,000 psi at test age of 2 hr ≥ 5,000 psi at test age of 1 day	Not reported	3,230 psi @ 2hr	Pass –2 hr
C 78 Flexural Strength	≥ 350 psi at test age of 2 hr and 1 day	Not reported	404 psi @ 2 hr	Pass - 2 hr
C 882 Bond Strength	≥ 850 psi to OPC mortar ≥ 1,000 psi to self Test age of 1 day for both conditions	Not reported	Not Tested	Not Tested
C469 Modulus of Elasticity	≤ $3x10^6$ psi test at age of 2 hr ≤ $4x10^6$ psi test at age of 3 days	Not reported	$2.70x10^6$ @ 2hr	Pass-2 hr
C 531 Volumetric Expansion	≤ 7×10^{-6} in/in/°F test begins at age of 3 days	Not reported	Not Tested	Not Tested
C 157 Volumetric Expansion	<+0.03% Expansion or <-0.04% Shrinkage @ 28 Days	Not reported	Not Tested	Not Tested
C 1581 Shrinkage Potential	≤ 40 microstrain at 14 days and no cracking at 28 days	Not reported	Not Tested	Not Tested
C 666 Freeze-Thaw Resistance	No requirement at this time	Not reported	Not Tested	Not Tested
C 191 Time of Setting	No requirement at this time	Not reported	Set – 26 minutes Final–29 minutes	NA

Additional Product Information

Shelf life/Storage conditions

None reported.

Packaging and yield

None reported.

Additional material requirements

None reported.

Mixing method/equipment

None reported.

Cleanup

Clean tools as soon as possible with water.

Safety Hazards

See Material Safety Data Sheets.

Unique test conditions

None reported.

Handling/Use Notes

None reported.

Rigid Repair Material Evaluation Report

Product Name:	Rapid Set Concrete Mix 73°F	**Material Description:**	Rapid Repair Concrete
Manufacturer Name and Contact Information:	CTS Cement		
NSN/GSA#:			
Evaluated by:	Missouri S&T (MST)		
Date:	2010	**Result: (Pass or Fail):**	Pass

Result Details

ASTM Test	Criteria	Manufacturer Test Result	Laboratory Test Result	Pass/Fail
C 39 Compressive Strength	≥ 3,000 psi at test age of 2 hr ≥ 5,000 psi at test age of 1 day	Not reported	3,730 psi @ 2hr	Pass –2 hr
C 78 Flexural Strength	≥ 350 psi at test age of 2 hr and 1 day	420 psi @ 2 hr 650 psi @ 1 day	420 psi @ 2 hrs	Pass - 2 hr
C 882 Bond Strength	≥ 850 psi to OPC mortar ≥ 1,000 psi to self Test age of 1 day for both conditions	Not reported	Not Tested	Not Tested
C469 Modulus of Elasticity	≤ $3x10^6$ psi test at age of 2 hr ≤ $4x10^6$ psi test at age of 3 days	Not reported	$2.75x10^6$ @ 2hr	Pass-2 hr
C 531 Volumetric Expansion	≤ 7×10^{-6} in/in/°F test begins at age of 3 days	Not reported	Not Tested	Not Tested
C 157 Volumetric Expansion	<+0.03% Expansion or <-0.04% Shrinkage @ 28 Days	Not reported	Not Tested	Not Tested
C 1581 Shrinkage Potential	≤ 40 microstrain at 14 days and no cracking at 28 days	Not reported	Not Tested	Not Tested
C 666 Freeze-Thaw Resistance	No requirement at this time	No sign of spalling@ 300 cycles. Average weight loss of 0.4%.	Not Tested	Not Tested
C 191 Time of Setting	No requirement at this time	Initial- 15minutes Final–35 minutes	Set – 21.5 minutes Final–22.5 minutes	NA

Additional Product Information

Shelf life/Storage conditions

None reported.

Packaging and yield

Material is packaged in 60 pound bags. Yield is not reported.

Additional material requirements

Water added at 3 to 5 quarts of water per 60 pounds of material. 4 quarts of water per 60 pounds of Rapid Set Concrete was used for laboratory testing.

Mixing method/equipment

Mixed with laboratory drum mixer. All water was added up front into a pre-wetted mixer. One bag of material was added at a time and was mixed with a few revolutions of the drum. After all materials were added, this material was mixed for 1 to 2 minutes until uniform.

Cleanup

Clean tools as soon as possible with water.

Safety Hazards

See Material Safety Data Sheets.

Unique test conditions

Specimens were cured for approximately 1 hour in laboratory conditions and final curing was ±73°F and ±50% humidity unless noted.

Handling/Use Notes

Mix was very workable.

Rigid Repair Material Evaluation Report

Product Name:	Set 45 HW	**Material Description:**	Rapid Repair Concrete
Manufacturer Name and Contact Information:	None reported		
NSN/GSA#:			
Evaluated by:	Missouri S&T (MST)		
Date:	2010	**Result: (Pass or Fail):**	Fail

Result Details

ASTM Test	Criteria	Manufacturer Test Result	Laboratory Test Result	Pass/Fail
C 39 Compressive Strength	≥ 3,000 psi at test age of 2 hr ≥ 5,000 psi at test age of 1 day	Not reported	2,220 psi @ 2hr	Fail–2 hr
C 78 Flexural Strength	≥ 350 psi at test age of 2 hr and 1 day	Not reported	275 psi @ 2 hr	Fail- 2 hr
C 882 Bond Strength	≥ 850 psi to OPC mortar ≥ 1,000 psi to self Test age of 1 day for both conditions	Not reported	Not Tested	Not Tested
C469 Modulus of Elasticity	≤ $3x10^6$ psi test at age of 2 hr ≤ $4x10^6$ psi test at age of 3 days	Not reported	$2.95x10^6$ @ 2hr	Pass-2 hr
C 531 Volumetric Expansion	≤ 7×10^{-6} in/in/°F test begins at age of 3 days	Not reported	Not Tested	Not Tested
C 157 Volumetric Expansion	<+0.03% Expansion or <-0.04% Shrinkage @ 28 Days	Not reported	Not Tested	Not Tested
C 1581 Shrinkage Potential	≤ 40 microstrain at 14 days and no cracking at 28 days	Not reported	Not Tested	Not Tested
C 666 Freeze-Thaw Resistance	No requirement at this time	Not reported	Not Tested	Not Tested
C 191 Time of Setting	No requirement at this time	Not reported	Set – 30 minutes Final–35 minutes	NA

Additional Product Information

Shelf life/Storage conditions

None reported.

Packaging and yield

None reported.

Additional material requirements

None reported.

Mixing method/equipment

None reported.

Cleanup

Clean tools as soon as possible with water.

Safety Hazards

See Material Safety Data Sheets.

Unique test conditions

None reported.

Handling/Use Notes

None reported.

Rigid Repair Material Evaluation Report

Product Name:	Speedcrete 2028	**Material Description:**	Rapid Repair Concrete
Manufacturer Name and Contact Information:	None reported		
NSN/GSA#:			
Evaluated by:	Missouri S&T (MST)		
Date:	2010	**Result: (Pass or Fail):**	Fail

Result Details

ASTM Test	Criteria	Manufacturer Test Result	Laboratory Test Result	Pass/Fail
C 39 Compressive Strength	≥ 3,000 psi at test age of 2 hr ≥ 5,000 psi at test age of 1 day	Not reported	1,930 psi @ 2hr	Fail –2 hr
C 78 Flexural Strength	≥ 350 psi at test age of 2 hr and 1 day	Not reported	353 psi @ 2 hr	Pass - 2 hr
C 882 Bond Strength	≥ 850 psi to OPC mortar ≥ 1,000 psi to self Test age of 1 day for both conditions	Not reported	Not Tested	Not Tested
C469 Modulus of Elasticity	≤ $3x10^6$ psi test at age of 2 hr ≤ $4x10^6$ psi test at age of 3 days	Not reported	$2.40x10^6$ @ 2hr	Pass-2 hr
C 531 Volumetric Expansion	≤ 7×10^{-6} in/in/ºF test begins at age of 3 days	Not reported	Not Tested	Not Tested
C 157 Volumetric Expansion	<+0.03% Expansion or <-0.04% Shrinkage @ 28 Days	Not reported	Not Tested	Not Tested
C 1581 Shrinkage Potential	≤ 40 microstrain at 14 days and no cracking at 28 days	Not reported	Not Tested	Not Tested
C 666 Freeze-Thaw Resistance	No requirement at this time	Not reported	Not Tested	Not Tested
C 191 Time of Setting	No requirement at this time	Not reported	Set – 34 minutes Final–38.5 minutes	NA

Additional Product Information

Shelf life/Storage conditions

None reported.

Packaging and yield

None reported.

Additional material requirements

None reported.

Mixing method/equipment

None reported.

Cleanup

Clean tools as soon as possible with water.

Safety Hazards

See Material Safety Data Sheets.

Unique test conditions

None reported.

Handling/Use Notes

None reported.

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Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT:

Numerous commercial-off-the-shelf products are available for small surface repairs in portland cement concrete (PCC) pavements that provide short set times, high early strengths, and durability to withstand heavy loads. Investigations of pavement repair materials conducted at the U.S. Army Engineer Research and Development Center (ERDC) in Vicksburg, MS, and other test organizations examined cementitious rapid-setting repair materials for repair of PCC pavements through laboratory and field characterization. Standard laboratory tests were performed to characterize the material properties over time and to provide a mechanism for assessing the material suitability for field repairs. Numerous repairs were constructed and evaluated under controlled traffic conditions to determine the ability of the repairs to support aircraft traffic after a minimum curing period. A laboratory protocol was developed for selection of cementitious, rapid-setting repair materials based on the laboratory and full-scale test results. This protocol originally developed in 2006, aided airfield managers and repair teams by reducing the potential for selection of materials that were likely to perform poorly. Changes to the protocol were made based on a review of material properties and field performance of materials tested at ERDC and other test agencies to improve the process of selecting materials based on repair type and size.

15. SUBJECT TERMS

Crater repair
Full slab replacement
Large patch
Pavement repair
Rapid-setting material
Small patch
Testing protocol

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
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